Universidade de Lisboa
Faculdade de Ciências
Departamento de Biologia Animal

Impact of slash-and-burn agriculture on key-species regeneration, Cusseque, Angola

Ana Filipa Piedade

Dissertação
Mestrado em Biologia da Conservação

2013

Universidade de Lisboa
Faculdade de Ciências
Departamento de Biologia Animal

UNIVERSIDADE DE LISBOA

Impact of slash-and-burn agriculture on key-species regeneration, Cusseque, Angola

Ana Filipa Piedade

Dissertação
Mestrado em Biologia da Conservação

Orientador interno: Drª Cristina Máguas (FCUL)

Orientador externo: Drº Manfred Finckh (UH)

2013

Agradecimentos

Ao Manfred Finckh e à Cristina Máguas, por terem aceite supervisionar o meu trabalho, oferecido disponibilidade e apoio, e contribuído para que pudesse visitar um dos mais belos continentes do mundo.

Ao Jens, Rasmus, Cynthia, Monika, Ingo, Thomas, Andrzej, Johannes, Henrike, Zakia, Tene, Ute, Norbert, Laura, Kathrin, Daniel e a todo o grupo de trabalho em Hamburgo, pelo apoio, motivação e críticas construtivas, bem como pela companhia divertida e agradável. Em especial, à Friederike, pelo espírito, amizade única, alegria de viver e presença. Pelas nossas aventuras e desventuras por terras africanas (*chindeli!*).

Aos meus eternos amigos e à minha família, pela constante presença, apoio e motivação. Ao Pedro, pelo amor, presença, optimismo, motivação e força interior, pelo presente e pelo futuro. Ao Cláudio, pela capacidade de raciocínio única e ajuda indispensável, pelo exemplo de força interior e pela nossa amizade única. Aos meus pais, Henrique e Cândida, pelo amor, amizade, paciência e apoio, bem como por todas as oportunidades que me proporcionaram.

A todos, obrigada do fundo do coração.

Abstract

Thousands of people depend on the Okavango basin to support their livelihoods. Different authors have researched about slash-and-burn agriculture, but little is known about its impacts on the natural vegetation of Angola. This study aimed to assess how much traditional communities impact the regeneration of certain woody species - relevant to their own livelihoods - through slash-and-burn agriculture.

The study area was at Cusseque, Angola. Free-listing sessions were conducted to understand how wild woody plants were prioritized by the community and 55 people participated in the exercise. Thirty people answered to semi-structured enquiries about their agricultural practises. Slash-and-burn fields were mapped and categorized according to their age. Twenty-one key-species were selected from the free-listing results and their presence-absence, coverage, height and regeneration type were assessed in 21 field plots. Data from non-disturbed forest was added as a control group.

Locals identified 61 different woody species used for five purposes. *Erythrophleum africanum* was the most mentioned and used tree. Forest patches for agriculture are usually burned twice, fields are used for about 1 to 3 years, resting years do not usually exceed 3 years, the main source of manure is ash and the most important crop is maize. Key-species regenerated in the plots across the age-field categories. However, differences in cover values were noted. *Brachystegia spiciformis* and *Cryptosepalum exfoliatum ssp. pseudotaxus* were the most abundant species in all field categories. Vegetative regeneration was predominant and only nine out of the 21 key-species managed to reach at least 1 m height, while only six reached at least 50 cm of perimeter.

This study suggests that slash-and-burn agriculture impacts to some extent the regeneration of key-species. However, the lack of information regarding the key-species limited the understanding of regeneration dynamics. Therefore, further research in the area is critical for an efficient conservation of these species.

Keywords: slash-and-burn agriculture, woody plants, key-species, traditional communities, Angola

Resumo

Milhares de pessoas dependem directamente dos recursos naturais oferecidos pela Bacia do Rio Okavango para a sua subsistência. Uma grande parte da população de Angola, Botswana e Namíbia ainda vive em condições de extrema pobreza, em especial Angola devido à passada guerra civil. Como consequência deste conflito armado, a agricultura de subsistência foi extremamente afectada, forçando a maioria das pessoas a viver um estilo de vida nómada. Em 1985, cerca de 300 a 500 milhões de pessoas dependiam da agricultura de corte-e-queima, a grande maioria vivendo em regiões tropicais. Diversos autores investigaram os impactos da agricultura de corte-e-queima em diferentes países africanos, mas pouco ainda se sabe sobre os efeitos deste tipo de agricultura de subsistência na vegetação natural de Angola. Assim, o presente estudo tem com objectivo descobrir se as comunidades tradicionais da região do Cusseque estão a afectar a regeneração de certas espécies de plantas lenhosas - as quais são relevantes para a sua própria subsistência - através do uso de práticas de agricultura de corta-e-queima. Assim, três questões foram propostas: (1) Quais são as espécies de plantas lenhosas mais importantes para as comunidades locais, bem como os seus usos?; (2) Como é que a agricultura de corta-e-queima é praticada na região do Cusseque?; (3) Em que medida as espécies-chave são afectadas pela agricultura de corte-e-queima?

A área de estudo localiza-se no núcleo de investigação do projecto TFO, em Cusseque, Angola, o qual situa-se na parte superior da Bacia de Okavango. O tipo de vegetação predominante é a floresta de miombo, a qual é essencialmente ocupada por espécies do género *Brachystegia*. O clima é tropical com estação seca, com uma precipitação anual que varia entre os 900 e os 1100 mm por ano. As chuvas ocorrem durante os meses de Verão (Setembro e Março) e as temperaturas médias variam entre os 17 e os 30°C.

De forma a se obter uma visão mais detalhada e holística sobre o real impacto das práticas de corta-e-queima na vegetação local, foram usadas tanto uma abordagem etnobotânica como ecológica. Sessões de *free-listing* foram conduzidas para a compreensão de como é que as plantas lenhosas eram priorizadas pela comunidade, e um total de 55 pessoas (24M:31F) foram envolvidas nas sessões. As categorias de uso pré-seleccionadas foram construção, alimentação, medicina, tintas e superstição. As espécies de árvores obtidas foram registadas de acordo com a ordem em que foram mencionadas, i.e. espécies mencionadas em primeiro lugar foram associadas a um maior nível de importância. Inquéritos semi-estruturados foram também preparados de forma a aprofundar o conhecimento sobre as práticas de agricultura de corta-e-queima naquela área de estudo específica. Trinta pessoas foram entrevistadas individualmente, com um *sex ratio* de 17M:13F.

Campos de agricultura de corta-e-queima foram mapeados e categorizados de acordo com as suas idades, resultando em três grupos diferentes: recente, médio e antigo. *Recente*

diz respeito a todos os campos que foram cortados e queimados recentemente, i.e., entre 2011 e 2010, e que ainda estão em uso. *Médio* inclui todos os campos que foram cortados e queimados em 2009 e 2008 e que ainda estão em uso pelas populações locais. Finalmente, *antigo* inclui campos que já foram cortados, queimados e usados no passado, mas que estão actualmente abandonados pelas comunidades locais. Sete dos inicialmente mapeados campos de agricultura foram escolhidos para cada uma das categorias, resultando em um total de 21 campos independentes. A informação referente à idades dos campos foi obtida através da ajuda do assistente de campo local.

Vinte e uma espécies-chave (i.e. as espécies lenhosas mais relevantes para as comunidades, baseadas nas categorias de uso pré-estabelecidas) foram seleccionadas a partir dos resultados da *free-listing*. Em cada campo de agricultura de corta-e-queima, um plot de 50 x 20 m foi colocado sobre a vegetação, no qual se incluiu um outro plot de 10 x 10 m. No quadrado de 10 x 10 m, a presença-ausência (i.e. número de espécies-chave encontradas no plot) e a cobertura das espécies-chave foram anotadas. Adicionalmente, para indivíduos pertencentes à lista de espécies-chave com mais de um metro de altura, a altura total e o tipo de regeneração que apresentavam (vegetativa ou por semente) foram anotados. No plot de 50 x 20 m, árvores inteiras, com pelo menos 50 cm de perímetro, e pertencentes à lista de espécies-chave, tiveram a sua altura total medida. Mais tarde, dados obtidos em floresta não perturbada por práticas de agricultura foram adicionados como grupo de controlo, cortesia de Rasmus Revermann.

As comunidades locais identificaram 61 plantas usadas em pelo menos um dos cinco usos pré-estabelecidos. *Erythrophleum africanum* foi a espécies mais mencionada e usada pelos locais. De acordo com as descobertas deste estudo para a região em questão, as áreas florestais escolhidas para agricultura são queimadas duas vezes, os campos são usados durante cerca de um a três anos e o repouso das terras não costuma ultrapassar os três anos, sugerindo alguma intensidade de fogo e um período de repouso curto, o último tendo já sido diversas vezes citado por outros autores como uma das principais razões para a não sustentabilidade destas práticas agrícolas. As espécies-chave foram encontradas a regenerar nos plots ao longo das categorias de campo, no entanto, os valores de cobertura variaram. Os plots mais antigos tiveram valores baixos em relação ao que era expectável. Quatro dos sete campos antigos foram encontrados cobertos de fetos, *Pteridium aquilinum*, espécie esta que já foi diversas vezes relacionada com o atraso na regeneração de florestas, afectando a riqueza específica e a abundância de árvores e arbustos. *Brachystegia spiciformis* e *Cryptosepalum exfoliatum ssp. pseudotaxus* foram as duas espécies-chave mais abundantes nas quatro categorias de campo (incluindo no grupo de controlo). A regeneração vegetativa foi encontrada como sendo predominante em relação à regeneração por semente, em especial nos plots da categoria recente. O fogo já foi anteriormente conectado à morte de sementes na superfície de solos, podendo ser esta a razão para a baixa regeneração por sementes nesta categoria de campo. Mais espécies-chave atingiram maiores alturas nos campos mais antigos, em comparação com os campos médios e recentes. Esta diferença foi mais acentuada nos plots de 10 x 10 m, pois a grande maioria das árvores tinha sido cortada e, por isso, a regeneração vegetativa era predominante. Somente nove indivíduos das iniciais 21 espécies-chave conseguiram atingir um metro de altura. De forma semelhante, somente indivíduos de seis espécies-chave foram identificadas como tendo um perímetro de pelo menos 50 cm.

Os resultados deste estudo sugerem que a agricultura de corte-e-queima afecta a regeneração das espécies-chave. No entanto, a falta de informação sobre estas espécies limitou a compreensão mais profunda sobre a dinâmica de regeneração. Desta forma, mais estudos botânicos sobre as espécies em questão são essenciais, de forma a se colmatar esta falta de conhecimento. Este estudo contribuiu igualmente para uma melhor compreensão sobre as práticas de agricultura de corta e queima na área, bem como as particularidades associadas à mesma. A informação obtida será certamente relevante para suportar futuros estudos na área relacionados com este tipo de agricultura e os seus impactos na vegetação natural. Adicionalmente, os resultados obtidos relacionados com o conhecimento local sobre as plantas nativas destacam a importância de documentar o quanto antes o conhecimento das comunidades tradicionais da área do Cusseque, antes que o mesmo seja perdido para sempre.

Palavras-chave: agricultura de cortar-e-queimar, plantas lenhosas, espécies-chave, comunidades tradicionais, Angola

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Introduction

The Okavango river has its source in the rainy highlands of Angola and is one of the largest perennial rivers in Southern Africa, terminating in the world's largest Ramsar site, the Okavango Delta in Botswana [1], designated as the country's first Wetland of International Importance. It comprises the Cuito, Cubango and Okavango subcatchments and its active part that supplies almost all water to the river is wholly located in south-central Angola, comprising about 112,000 km^2 [2].

Only recently the basin is coming under land use pressure as a result of economic change in the basin countries, i.e. Angola, Namibia and Botswana [2], hence still keeping much of its natural vegetation. About 600,000 people depend on the Okavango Basin, 58% of them living in the basin area of Angola [2]. Thus, the relative highest population densities are found in the upper Cubango catchment in Angola, nevertheless with a low absolute population density since people living in the basin area of Angola represent less than 3% of the total population of this country.

A great part of the population of Angola, Botswana and Namibia still live in extreme poverty, particularly in Angola due to the past civil war [2]. Due to this armed conflict, which started in 1975 and only ended in 2002, agriculture was heavily affected [3] and, in 1990, the use of mines as well as bombers almost completely collapsed farming practises. In the Bié province, the conflicts were particularly harsh, heavily affecting subsistence agriculture and forcing a nomadic way of life to most of the people. Angola has more than 20 million inhabitants, from which about 67% lives in poverty [2]. In 2010, it was ranked 146th out of 187 countries in terms of human development [3] and it is estimated that about 40% of the people are undernourished [3].

Due to this high incidence of poverty in the basin, the majority of people depend on natural resources freely available from the river and surrounding areas to support their livelihoods [2]. Tropical regions are rich in animal and plant biodiversity [4], however, they are also more prone to high biodiversity losses [5] [6]. In fact, between 1970 and 2008, the tropical terrestrial biodiversity index showed a decline of around 45%, while the Afrotropical index declined by 38% [7]. Tropical deforestation related to land use practises is thought to be one of the main key drivers of tropical biodiversity loss [8] [9].

According to Kgathi et al [2], more people are dependent on farming in Angola than in other parts of the basin, with an estimation of 60,000 farmers involved in small scale arable farming. Only 5% of the households have access to cattle in the Angolan basin [10]. Slash-and-burn agriculture, a type of shifting cultivation, is an old and common farming practise [4]. Variations of this type of cultivation have been used for centuries [4] and, in 1996, Brady [4] quoted a FAO report of 1985 which stated that between 300 and 500 million people depended on slash-and-burn agriculture, the great majority living in tropical regions. The general concept of this kind of agriculture is simple. A certain area of forest is slashed and burned down, so that nutrients accumulated into the biomass are released into the soil (Figure 1.1). Following this procedure, the patch is used for cultivation until the soil loses fertility and the need to slash and burn down another forest area emerges, restarting the cycle. The fallow is then left alone and so the ecological succession is resumed. Trees, shrubs and grasses grow up and accumulate nutrients in their biomass, and organic matter returns to the soil [4].

Figure 1.1: Patch of forest after slash and burn (Cusseque, Angola)

Traditional slash-and-burn agriculture used to be sustainable since it was practised on a small or local scale and fallow periods were longer [4] [11] [12]. However, due to the increase of population densities in the last decades [4], a higher pressure on the land slowly reduced fallow periods, affecting plant regeneration and average biomass on the land [12].

Most carbon is stored in tropical forests [7]. Above-ground biomass stores are about 247 GtC (gigatonnes of carbon) in tropical forests, from which 25% is in the Africa, hence highlighting their importance in climate stabilization [7]. However, the presence of fire in slash-and-burn agriculture naturally releases this carbon into the atmosphere, contributing to climate change [13]. Slash-and-burn agriculture is also connected to deforestation, rapid soil and land degradation, poor crop yields, biodiversity losses, changes in water infiltration rates and run-off rates of the soil [11] [12] [13] [14]. Due to the past civil war, scientific research was very affected and thus there is still a big knowledge gap about the impact of slash-and-burn agriculture in the forests of Angola.

1.2 Research Aim

The aim of this study was to assess if the practise of slash-and-burn agriculture by the local communities in the Cusseque area impacts the regeneration of a selected group of woody key-species, which are particularly relevant to their own livelihoods. For this, both ethnobotanical and ecological approaches were used in order to obtain a more holistic and detailed vision of the real impact of this practice on the local vegetation.

The main hypothesis is that the practise of slash-and-burn agriculture impacts the regeneration of this selected group of woody key-species. Therefore, the main research questions are the following:

1) Which woody species are most important for the local communities and what are they used for?
2) How is slash-and-burn agriculture practised in the Cusseque area?
3) How are key-species affected by slash-and-burn agriculture?

The present study is inserted in the context of the TFO-Project [15].

Chapter 2

Methods

2.1 Study Area

The study area was the research core site of TFO's research project at Cusseque, Angola (Figure 2.1), in the upper part of the Okavango basin (Figure 2.2) (northwest core site coordinates: S13°40'45.35" E16°56'32.25"; southeast core site coordinates: S13°43'22.43" E17°07'39.09"). This included four small villages at both sides of the Cusseque river, about 40 km south-east of Chitembo, in the Bié province of Angola. Bié has about 1.2 million people of 19 different ethnicities [3] and, in 2011, the municipality of Chitembo comprised alone about 99,745 inhabitants [3]. The four villages at the core site are Caololo, Sovi, Cusseque (it has the same name as the study area) and Calomba. The population of these villages is mainly Chokwe and most people know how to speak Portuguese.

Cusseque, as well as a great part of Bié, is composed by dense *Brachystegia* miombo forests with open valleys and floodplains, which constitutes the Zambezian biome [16] (Figure 2.3). This biome covers about 80% of the national territory with miombo forests occupying 47% of the country [17]. Cusseque has tropical summer rainfall climate with an annual total precipitation ranging between 900 and 1100 mm per year [3]. Rainfalls occur during the summer months (September to March) and monthly mean temperatures range between 17 and 30°C [3] (Figure 2.4).

2.2 Data Collection

Ethnobotanical Approach

Free-Listing Sessions

Due to the fact that traditional communities still live essentially off the land, the free-listing method [18] was used to understand how wild woody plants were categorized and prioritized by the community of the core site. For this, informants were asked to list important plants regarding pre-selected uses. Free-listing sessions were conducted between October 12th 2012 and October 20th 2012 and the four villages were included: Caololo, Sovi, Cusseque and Calomba. A total of 7 free-listing sessions were held. Due to the difficulty of having individual and private sessions with the participants, group free-listings were

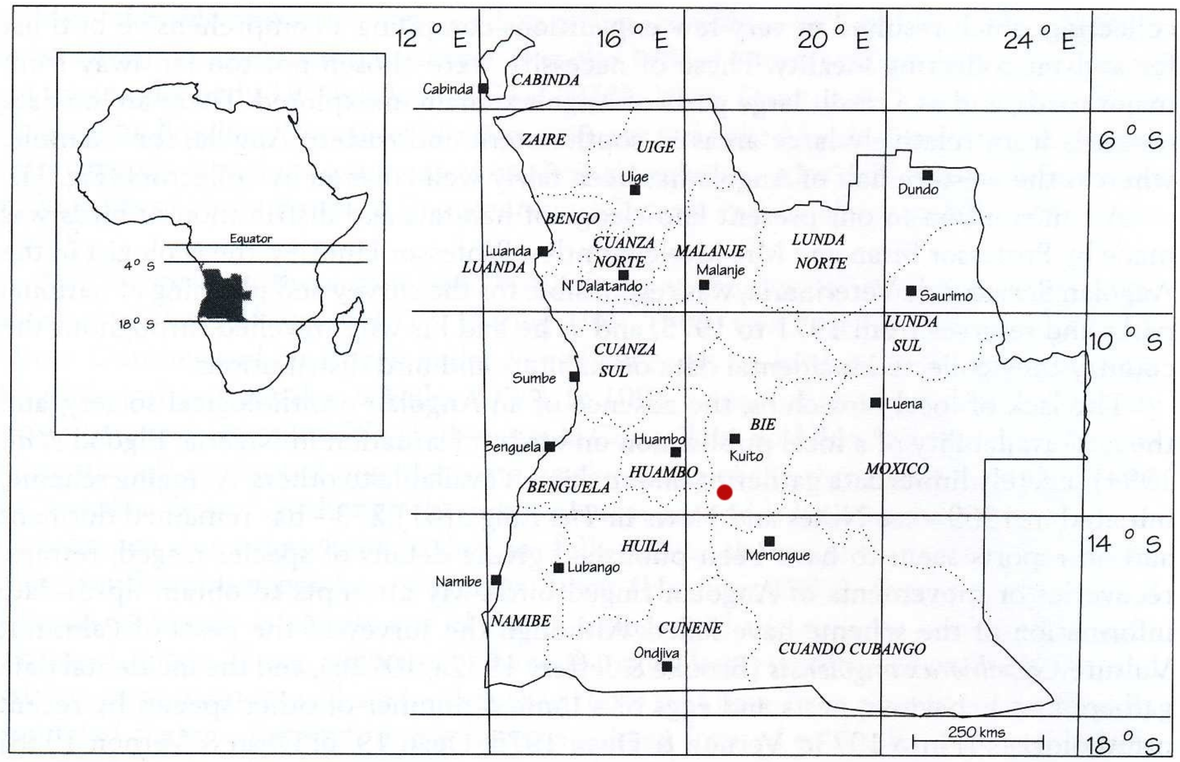

Figure 2.1: Position of Angola on the African continent, Angolan provincial capitals and major cities. Core-site's relative position marked in red (dot) [19]

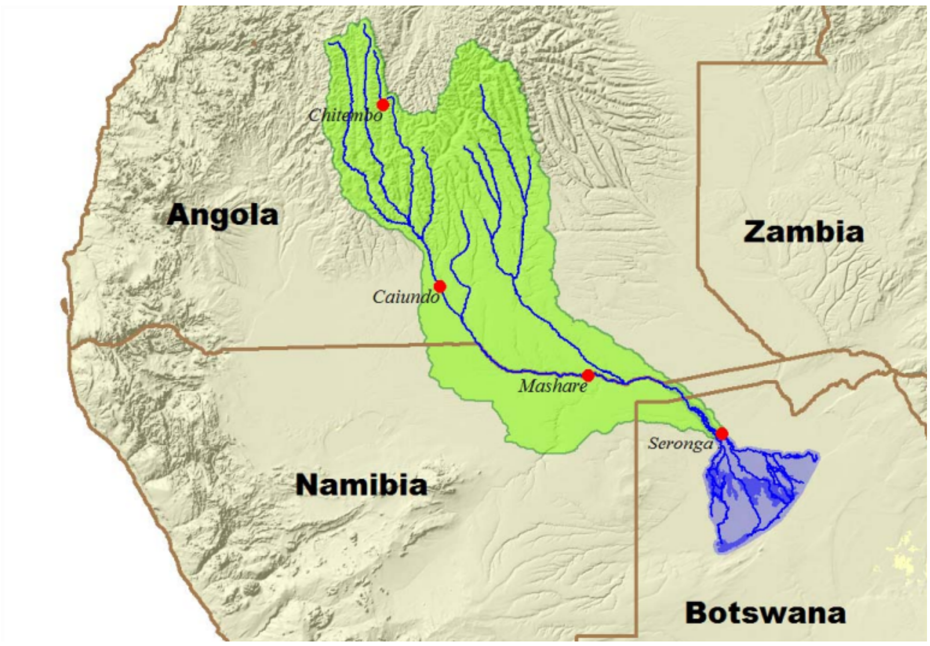

Figure 2.2: Okavango basin along Angola, Namibia and Botswana. The core site is about 40 km south-east of Chitembo [15]

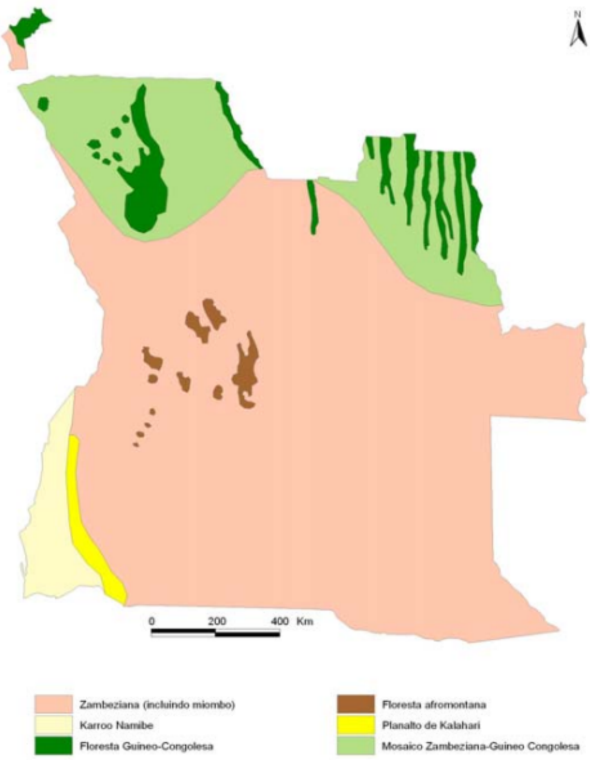

Figure 2.3: Biomes of Angola, including the Zambezian biome in pink colour [17]

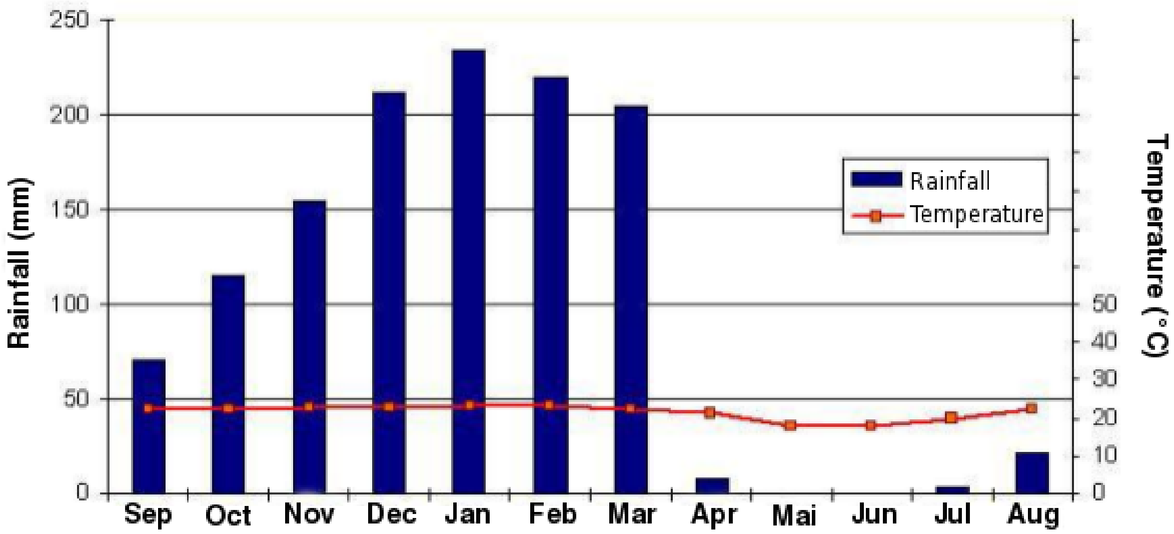

Figure 2.4: Monthly rainfall and mean temperatures for the Bié province (translated figure) [3]

conducted and both women and men participated. A total of 55 people (24M:31F) were involved in the sessions. The headman's permission to talk with villagers was asked beforehand and a TFO's para-ecologist fluent in Portuguese, English and Ubundu was present during the sessions to facilitate the conversation. During each session, participants were asked about which main plant species were used for different purposes. The following five categories were used: construction, food, medicinal purposes, dyeing purposes and rituals. These were particularly chosen due to the fact that people live quite isolated from the nearest city and therefore seem to rely on the surrounding vegetation for these purposes or activities.

Plant species were registered according to the mentioned order, i.e., species mentioned in the first place were given a higher importance rank. Plant names were usually referred in Chokwe, and sometimes in Ubundu and Ganguela. In order to not influence interviewees' answers, participants were allowed to mention as many plants as they remembered at the moment. Although this study focuses on woody species used for the categories mentioned above, participants were allowed to name other plants, such as herbaceous species, as well as add new categories to the already established, such as "Hives" and "Hygiene". Nevertheless, these categories and non-woody species were not considered in the key-species determination (key-species: most relevant woody plants for the community based on the pre-established use categories).

Semi-Structured Interviews

As referred before, slash-and-burn agriculture is very common in Angola, however, not so much information is available about it. Therefore, semi-structured enquiries [20] were prepared in order to learn more about how slash-and-burn agriculture is practised by the local communities in that specific area. Interviews were conducted between October 23rd 2012 and October 26th 2012 at the core site, and included people from Caololo and Sovi villages. These two villages were chosen out of the initial four due to the easier access to the people, specially since they were moving out from the central villages to their dispersed field houses and interviewees had to be reachable by foot. Thirty people were interviewed individually, with a sex ratio of 17M:13F. The same enquiry form was used for all interviewees, which contained 14 questions on slash-and-burn agriculture (Figures A.1 and A.2). More than one answer to the questions were allowed and considered in the data analysis.

Ecological Approach

Field Mapping

Different slash-and-burn fields of the core site were mapped with the Garmin GPS 72H's tracking function. For the purposes of fields' age identification and limits, a local guide was present to assist on this task. A total of 28 slash-and-burn fields were mapped with the GPS. These were found with the help of the field assistant, which usually preferred to take me to his family fields since it was not well seen to visit other's working fields without permission.

After the mapping task, fields were categorized into three different groups: recent, medium and old. *Recent* included all fields which had been slashed and burned recently, i.e., between 2011 and 2010, and were still in use. *Medium* comprised all fields which had been slashed and burned in 2009 or 2008 and were still used by the local people. Finally, *old* included fallows, i.e., fields which had been slashed, burned and used by the people in the past, but were abandoned on the time of this study (Figure 2.5). Seven of the initially mapped slash-and-burn fields were chosen per category, resulting in a total of 21 independent fields. Fields were chosen according to their age since the slash-and-burn event, and this information was obtained from the local field assistant. The old category was the only one which contained a greater field age range, while the two others were more balanced (Table 2.1). Landsat Satellite Imagery was used to confirm the real age of each field (resolution: 30 x 30 m).

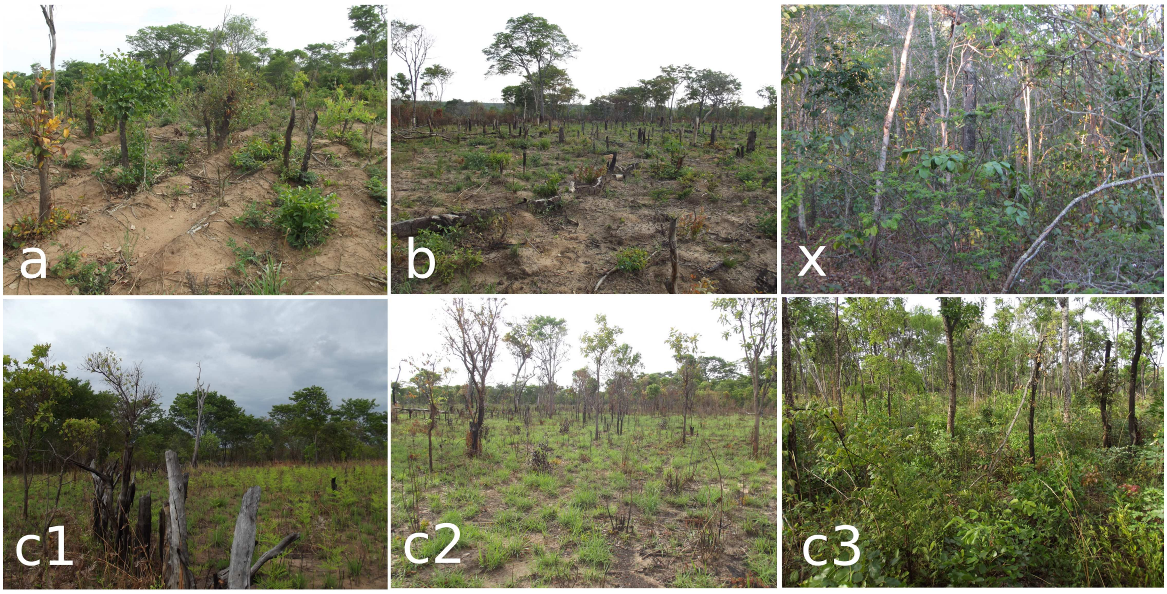

Figure 2.5: Pictures representing each field category. The three photos below (c) help to show the variability found between different old fields. Legend: a - Recent; b - Medium; c - Old; x - Control

Table 2.1: Age of the fields of the three main field categories. (*) "1900's" refers to a field which was slashed and burned before 2000. These were fallows and local people were not sure about their exact age.

	Old	**Medium**	**Recent**
Plot 1	1900's*	2008	2010
Plot 2	1900's*	2008	2010
Plot 3	2003	2009	2010
Plot 4	2003	2009	2011
Plot 5	2005	2009	2011
Plot 6	2006	2009	2011
Plot 7	2006	2009	2011

Seven extra fields (from the original 28 mapped sites) were excluded mainly for two reasons. The first was due to the fact that the field assistant got confused about some of the fields' ages, hence jeopardizing some of the categories which required a new organization.

The second reason was due to the limited time in the core site, which only allowed me to work on seven fields per category.

Later on, a *control* category was added to the previous three groups, which contained plots from fields in non-disturbed forest of the core site (Figure 2.5). A total of 13 control plots were added (nine plots from May 2011, two plots from November 2011 and two plots from April 2012), data courtesy of Rasmus Revermann (Figure 2.6 and Table A.1).

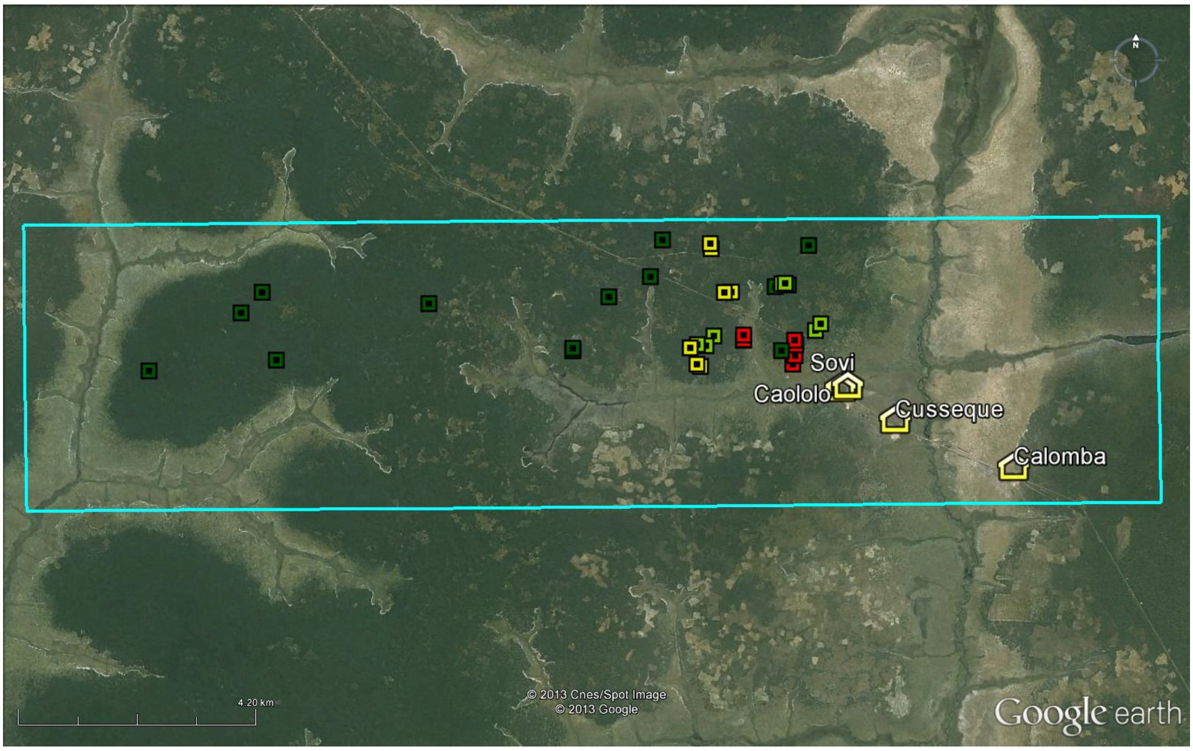

Figure 2.6: Location of the fields and villages. The blue frame represents the limits of the core site. Legend: Dark green markers - control plots; Light green markers - old plots; Yellow markers - medium plots; Red markers - recent plots; Yellow houses - villages

Plots

Slash-and-burn fields' assessment was conducted between November 14th 2012 and November 20th 2012. On each slash-and-burn field, a 50 x 20 m vegetation plot was done, in which a 10 x 10 m plot was included (Figure 2.7). On the 10 x 10 m square, key-species presence-absence (i.e. nº of key-species found on the plots) and their coverage were assessed. The later was visually assessed and estimated in percentage. Additionally, for key-species individuals with more than 1 meter high, their total height was estimated and regeneration type (vegetative or seed regeneration) noted. Vegetative regeneration usually happened from the top of the slashed trunks and therefore height measure included both the old trunk (mostly cut at around waist height) as well as the new branches (Figure 2.8). On the 50 x 20 m plot, non-slashed key-species trees with more than 50 cm perimeter had their total height measured with Haglöf Vertex IV Hypsometer.

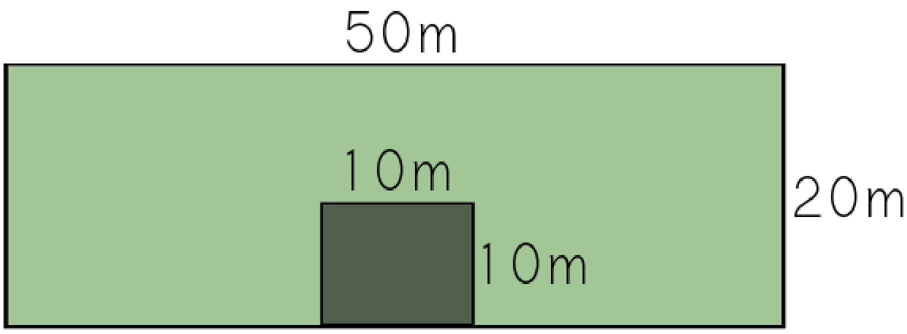

Figure 2.7: Sketch of the vegetation plot design. Drawing is not on scale

Figure 2.8: Example of vegetative regeneration from the top of the stump after slashing at around waist height

2.3 Data Analysis

In order to determine the key-species (i.e. the most relevant woody plants for the community based on the pre-established use categories) through the free-listings, plant names were organized in a list and sorted out according to the number of times they were mentioned in total. Then, plants mentioned at least 5 times were chosen, resulting in a total of 21 woody key-species (Table 2.2). Microsoft Excel 2010 was used for this key-species determination.

Table 2.2: Key-species' family, scientific name and Chokwe name. FNR: collection number of a specimen collected as reference

Family	**Scientific name**	**Chokwe name**
Anisophylleaceae	*Anisophyllea boehmii* Engl.	Mufungo
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	Mutongo
Combretaceae	*Terminalia brachystemma* Welw. ex Hiern	Mueya
Ebenaceae	*Diospyrus chamaethamnus* Dinter ex Mildbr.	Mujongolo
Ebenaceae	*Diospyros pseudomespilus* Mildbr. *ssp. brevicalyx* Mildbr.	Muchicala
Fabaceae	*Brachystegia spiciformis* Benth.	Mumanga
Fabaceae	*Brachystegia bakeriana* Burtt Davy & Hutch.	Chikungo
Fabaceae	*Bobgunnia madagascariensis* (Desv.) J.H.Kirkbr.	Mutete
Fabaceae	*Burkea africana* Hook.	Mussesse
Fabaceae	*Cryptosepalum exfoliatum* De Wild. *ssp. pseudotaxus* Baker f.	Mukue
Fabaceae	*Dialium englerianum* Henriq.	Mussala
Fabaceae	*Erythrophleum africanum* (Welw. ex Benth.) Harms	Mukosso
Fabaceae	*Guibourtia coleosperma* (Benth.) J.Léonard	Muchi
Fabaceae	*Julbernardia paniculata* (Benth.) Troupin	Munhumbe
Melastomataceae	*Warneckea sapinii* (De Wild.) Jacq.-Fél.	Muzele
Myrtaceae	*cf. Eugenia* [FNR 135873]	Musokua
Polygalaceae	*Securidaca longipedunculata* Fresen.	Muchacha
Rubiaceae	Rubiaceae [FNR 135866]	Mussole
Rubiaceae	cf. Rubiaceae [FNR 135872]	Mujindo
Strychnaceae	*Strychnos cocculoides* Baker	Mukolo
Strychnaceae	*Strychnos pungens* Soler.	Muhuma

Enquiries were analysed with the assistance of Microsoft Excel 2010 and field data used Past 2.17c [21] for statistical analysis. One-Way ANOVA was used in order to assess the differences between field categories in both key-species' presence-absence and coverage. Data normality was assessed with the Shapiro–Wilk test which, according to Razali and Wah [22], is the most powerful normality test when compared with Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. Nevertheless, the same article states that all these tests are less powerful when small sample sizes (30 or less) are used. Therefore, Normal Probability Plots were used as a complementary visual method to confirm Shapiro-Wilk results. When data normality was not found, a Kruskal-Wallis test was used due to fact it is a non-parametric method. A Chi^2 test (contigency table) was used to test the relation between field categories and the type of regeneration. Barcharts and stacked column charts were obtained with the assistance of Microsoft Excel 2010.

Multivariate analysis [23] was also used in order to see the relation between different variables in a multi-dimensional space. An analysis of similarities (ANOSIM) [23] with Bonferroni corrected p values provided a way to statistically test whether there was a significant difference between the different field categories regarding species composition and coverage. A Principal Coordinates Analysis (PCO) [23] in association with an analysis of similarities with R values helped to visualize dissimilarity and group clustering in multivariate space.

Finally, a SIMPER analysis [23] for both presence-absence and coverage provided information on which key-species were contributing the most to the found dissimilarities. Jaccard distance measure was used for species composition while Bray-Curtis was used for coverage [23].

Chapter 3

Results

3.1 Free-listing and Key-Species

Most interviewees were from Caololo (26), followed by Calomba (15), Cusseque (8) and Sovi (6). The age ranged between 17 and 80 years old (Figure A.3) and the great majority of the people were farmers (9M:30F) (Figure A.4). Male interviewees carried a wider variety of different jobs compared with female ones.

This exploratory study found out that locals were able to recall 61 different plant species used for construction, food, medicine, dyes and ritual practices. Tables 3.1 and 3.2 show the key-species as well as the purposes they were mainly used for.

A total of 11 key-species were used for construction, mainly *Erythrophleum africanum* (6), *Cryptosepalum exfoliatum ssp. pseudotaxus* (6), *Brachystegia spiciformis* (5), *Julbernardia paniculata* (5) and *Bobgunnia madagascariensis* (5). Eleven species were also referred as key food sources, most of them mentioned 6 and 5 times with the exception of *Erythrophleum africanum* (2) and *Diospyrus chamaethamnus* (2). Thirteen out of the 21 key-species were used for medicinal purposes, specially *Julbernardia paniculata* (5), *Burkea africana* (5), *cf. Eugenia* (5) and *Securidaca longipedunculata* (5). For dyeing purposes, 7 different species were mentioned, standing out *Guibourtia coleosperma* (3) and *Burkea africana* (3). Finally, only two species were said to be used for rituals purposes, specifically to avoid ghosts, with *cf. Eugenia* the most mentioned woody plant (7). *Erythrophleum africanum* was the only key-species used in all the five pre-established categories. It was also mentioned 12 times in total, which demonstrates the high level of importance of the species. *cf. Eugenia* and *Julbernardia paniculata* were also mentioned 12 and 11 times respectively, however, only used in 2 and 3 different categories.

3.2 Slash-and-Burn Enquiries

Most male interviewees' ages ranged between 21 and 25 years old, while most women stated they didn't know their own age (Figure A.5). All women were farmers, with the exception of one single woman which said she was also a midwife (Figure A.6). Regarding male jobs, most men were farmers as well, but many also held other jobs which seemed to

Table 3.1: Key-species uses given by local people in the Cusseque area with use categories. Plant species were ordered according to the number of categories in which they are used. Each number indicates how many times each key-species was mentioned for that particular use category

Scientific name	Construction	Food (Tree)	Medicinal	Dyes	Superstition
Erythrophleum africanum (Welw. ex Benth.) Harms	6	2	2	1	1
Guibourtia coleosperma (Benth.) J.Léonard	2		2	3	
Brachystegia spiciformis Benth.	5		1	1	
Dialium englerianum Henriq.		5	3	1	
Terminalia brachystemma Welw. ex Hiern	1		4	2	
Julbernardia paniculata (Benth.) Troupin	5		5	1	
Brachystegia bakeriana Burtt Davy & Hutch.	4		1		
Warneckea sapinii (De Wild.) Jacq.-Fél.	1	6			
Burkea africana Hook.			5	3	
cf. Eugenia [FNR 135873]			5		7
Parinari curatellifolia Planch. ex Benth.	1	6			
Strychnos pungens Soler.		5	1		
Bobgunnia madagascariensis (Desv.) J.H.Kirkbr.	5		1		
Diospyrus chamaethamnus Dinter ex Mildbr.		2	3		
Rubiaceae [FNR 135866]	1	5			
Cryptosepalum exfoliatum De Wild. *ssp. pseudotaxus* Baker f.	6				
Diospyros pseudomespilus Mildbr. *ssp. brevicalyx* Mildbr.		6			
Strychnos cocculoides Baker		6			
cf. Rubiaceae [FNR 135872]		6			
Securidaca longipedunculata Fresen.			5		
Anisophyllea boehmii Engl.		5			

Table 3.2: Key-species uses given by local people in the Cusseque area, with sum of use categories and total mentioned times. Plant species were ordered according to the nº of categories in which they are used

Scientific name	Sum of use categories	Total mentioned times
Erythrophleum africanum (Welw. ex Benth.) Harms	5	12
Guibourtia coleosperma (Benth.) J.Léonard	3	7
Brachystegia spiciformis Benth.	3	7
Dialium englerianum Henriq.	3	9
Terminalia brachystemma Welw. ex Hiern	3	7
Julbernardia paniculata (Benth.) Troupin	3	11
Brachystegia bakeriana Burtt Davy & Hutch.	2	5
Warneckea sapinii (De Wild.) Jacq.-Fél.	2	7
Burkea africana Hook.	2	8
cf. Eugenia [FNR 135873]	2	12
Parinari curatellifolia Planch. ex Benth.	2	7
Strychnos pungens Soler.	2	6
Bobgunnia madagascariensis (Desv.) J.H.Kirkbr. & Wiersema	2	6
Diospyrus chamaethamnus Dinter ex Mildbr.	2	5
Rubiaceae [FNR 135866]	2	6
Cryptosepalum exfoliatum De Wild. *ssp. pseudotaxus* Baker f.	1	6
Diospyros pseudomespilus Mildbr. *ssp. brevicalyx* Mildbr.	1	6
Strychnos cocculoides Baker	1	6
cf. Rubiaceae [FNR 135872]	1	6
Securidaca longipedunculata Fresen.	1	5
Anisophyllea boehmii Engl.	1	5

be considered as very important (Figure A.6). Nineteen people were from Caololo and 11 were from Sovi.

100% of the interviewees preferred spots inside the forest for their cropping fields instead of spots outside the forest. Also, 100% of the people agreed that they always cropped only once a year in the same field. Since slash-and-burn agriculture is so predominant in the Cusseque region, one question addressed exactly the way how fields were prepared for cropping. The results are shown in table 3.3, the grey colour highlighting those activities which were mentioned by more than 15 people (i.e. half of the interviewed population).

Table 3.3: Main steps taken for the preparation of the fields for cropping. Colour grey highlights the activities which received more than 15 answers, i.e. half of the interviewed population

Step	Action	N° Answers
1°	Find a good forest patch	4
2°	Cut all possible trees and shrubs	26
	Cut first the small trees/shrubs, then the big trees	3
	Cut the big trees	1
3°	Let the wood get dry	17
4°	Burn the wood	29
5°	Pile the wood	28
6°	Let the wood pile get dry	1
7°	Burn the wood pile	28
8°	Let it get cooler	1
9°	Wait for the rain	1
10°	Cut shrubs and grass	1
11°	Start farming activities	27

Field preparation usually starts by the cutting down of trees and shrubs of a certain patch of forest. In a separate question regarding why they do not cut down all trees, twenty-eight out of 30 interviewees stated that they usually do not manage it because some trees are too big, large or tough and therefore too difficult to slash down. Following comes the fire, burning most of the trunks down to ashes. Due to the fact that certain branches and trunks do not completely burn down, individual piles are built up and set on fire (Figure 3.1). This clearing of the fields allows the building of raised beds (soil beds that are raised above the surface of the ground) and thus the start of the cropping season itself.

According to 28 interviewees, the main cutting months are May, June, July and August (Figure 3.2). Also, the great majority of the participants (26) agreed that the best burning month was September. Only few people (6) referred which months were used for cropping and, according to their answer, cropping months ranged between October and January. All interviewees (30) answered they always crop the whole field every year. However, some exceptions were raised for special cases, such as lack of health or strength (8), delay in cropping (2) or if the person is lazy (1).

A typical characteristic of the slash-and-burn fields which belonged to Caololo and Sovi communities was that trees usually were not completely pulled out from the ground, but

Figure 3.1: Burning the piled branches

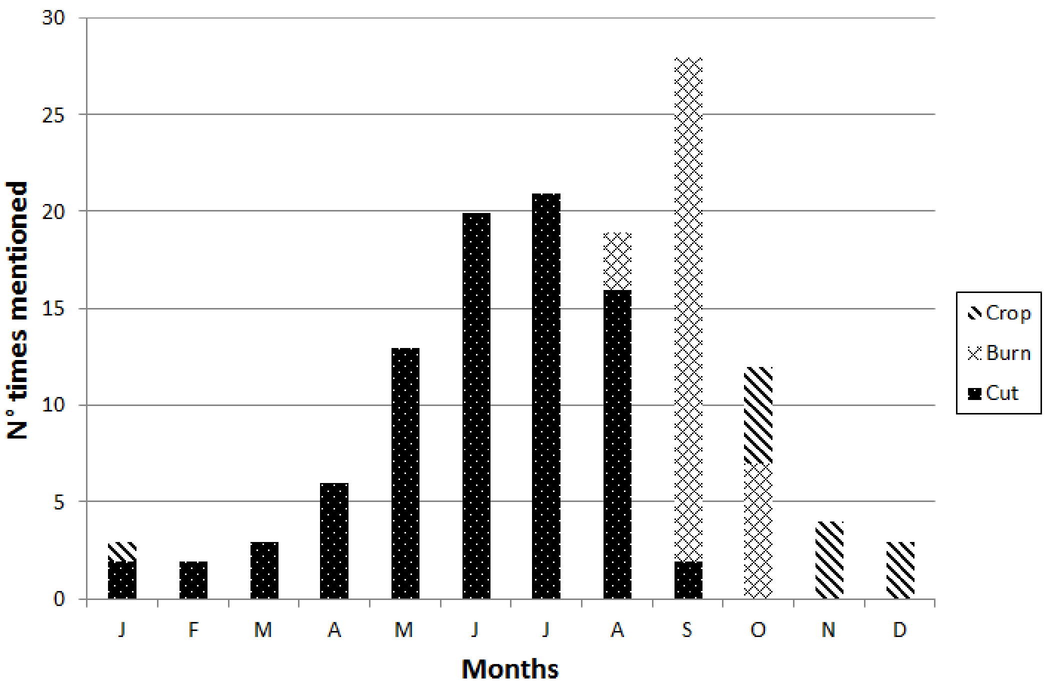

Figure 3.2: Main slashing, burning and cropping months

actually only cut down at around waist height. Therefore, one of the questions of the enquiry was about these trees and why they were not cut down close to the ground. Twenty-six out of 30 answered that was because they did not use oxen to till the soil.

Twenty-six people stated they burned the slashed trees for the manure they provided (Table 3.4). Many also stated that some of the cut wood could be alternatively used for other purposes such as house construction and fire wood, but only in exceptional cases.

Table 3.4: Stated reasons for burning the wood after slashing it. *Other* includes other possible uses that can be given to the wood in exceptional cases

Answers	**Nº Answers**
Manure	26
Clean the field/space to build the raised beds	5
Other uses applied to cut wood:	
Fire wood	22
House construction	15

After the field is burnt, the first action is to proceed with the building of raised beds and seeds are sown. The next step is to wait for the rain, for this agriculture system is rain fed. Later on, when the grass is already grown up, this is cut down and placed between the raised beds in order to fertilize the soil and avoid it casting shade over the crops. Table 3.5 displays these after slash-and-burn steps and the grey colour highlights those activities which were mentioned by more than 15 people (i.e. half of the interviewed population).

Table 3.5: Agricultural activities following slash and burn. Colour grey highlights the activities which received more than 15 answers, i.e. half of the interviewed population

Step	**Action**	**N° Answers**
1°	Mix earth with grass, leafs, etc	13
2°	Build raised beds	30
3°	Seeding	28
4°	Wait for the rain	28
5°	Cut the grass	21
6°	Cover the maize roots with dirt	3
7°	Use chemical fertiliser next to the maize roots	1

Eighteen out of 30 interviewees stated they usually explored their fields until their fertility limit (Table 3.6) and only 5 people said they usually cropped the same number of years for each field. The option "other" included the addition of 1 or 2 extra years in case of a good soil, the presence of cassava and the use of rotation schemes (Table 3.7).

When asked specifically about cropping years, these varied, however, the great majority seemed to prefer 1 to 3 years of cropping before moving on to a different field (Figure 3.3). If the field was exceptionally good (i.e. higher in fertility than the average field), then the cropping period on the same field could be extended up to 4 or 5 years (Figure A.7). When enquired about resting years, 20 people said that their fields rested for some years, while 10 stated they didn't have any resting years. Regarding how many years last a resting period, most people (11 out of 20) answered they usually let their fields rest for about one to three years, while only three said they would wait between four to five years.

Table 3.6: Answers regarding how slash-and-burn fields are usually exploited by the locals

Answers	**Nº Answers**
Exploited until the limit	18
Exploited always the same nº of times	5
Other	7

Table 3.7: Answers regarding how slash-and-burn fields are usually exploited by the locals: *Other* answers

***Other* Answers**	**Nº Answers**
If field good, plus 1 or 2 years only	5
Field used for cassava	1
Field rotation scheme	1

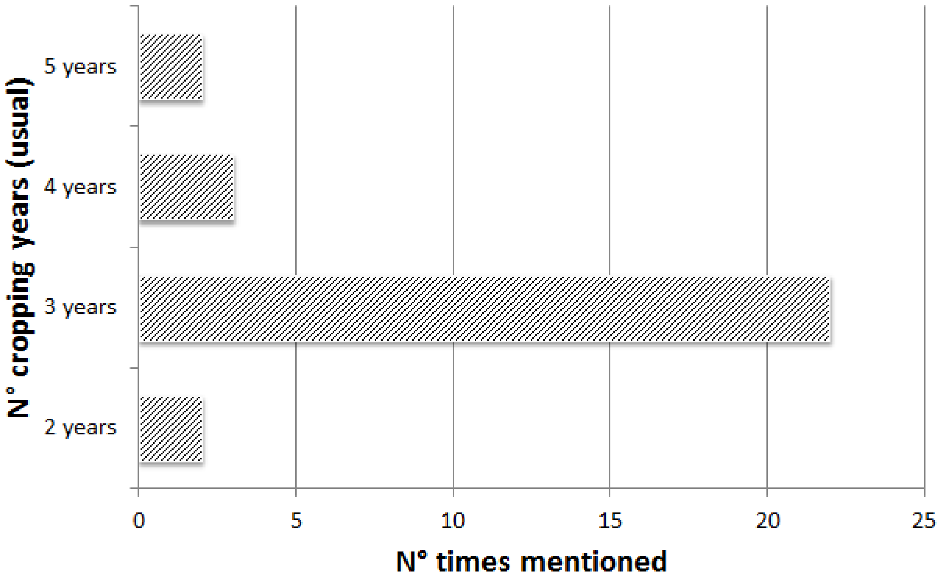

Figure 3.3: Usual number of cropping years in a slash-and-burn field before moving out to a new forest patch

The main sources of manure were ash and grass (Figure 3.4). Chemical fertilisers were mentioned by some as used in certain specific situation, such as low field fertility. Taking in consideration the order by which manure types were mentioned, therefore highlighting how importantly they are perceived by the respondents, the pattern was kept with ash and grass as the most important sources of manure (Figure A.8). Interviewees stated different criteria which were crucial for them to leave a certain field and look for another one. Out of the 30 answers, 28 stated that the most important criteria was the infertility of the fields. When asked about what they usually did when their fields were infertile, 19 out of 30 people stated they preferred to change to a new forest patch (Figure 3.5).

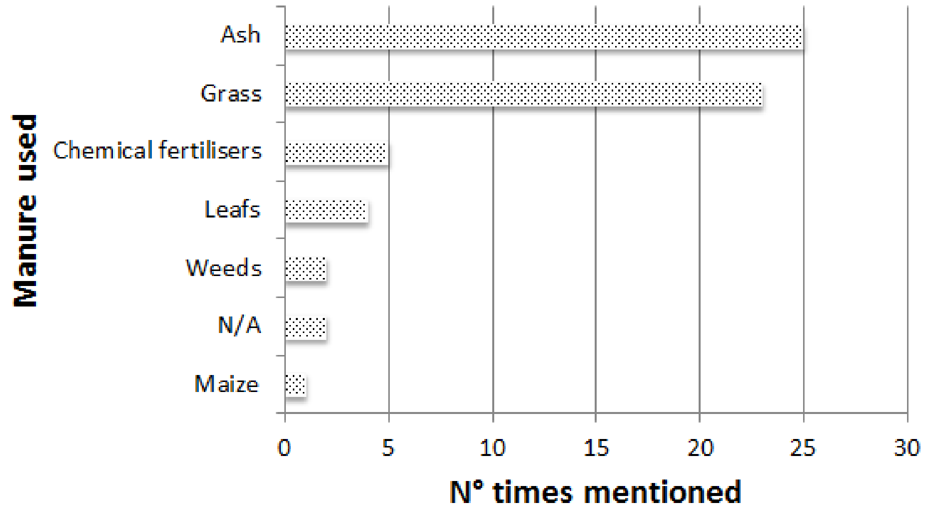

Figure 3.4: Main sources of manure used by local people

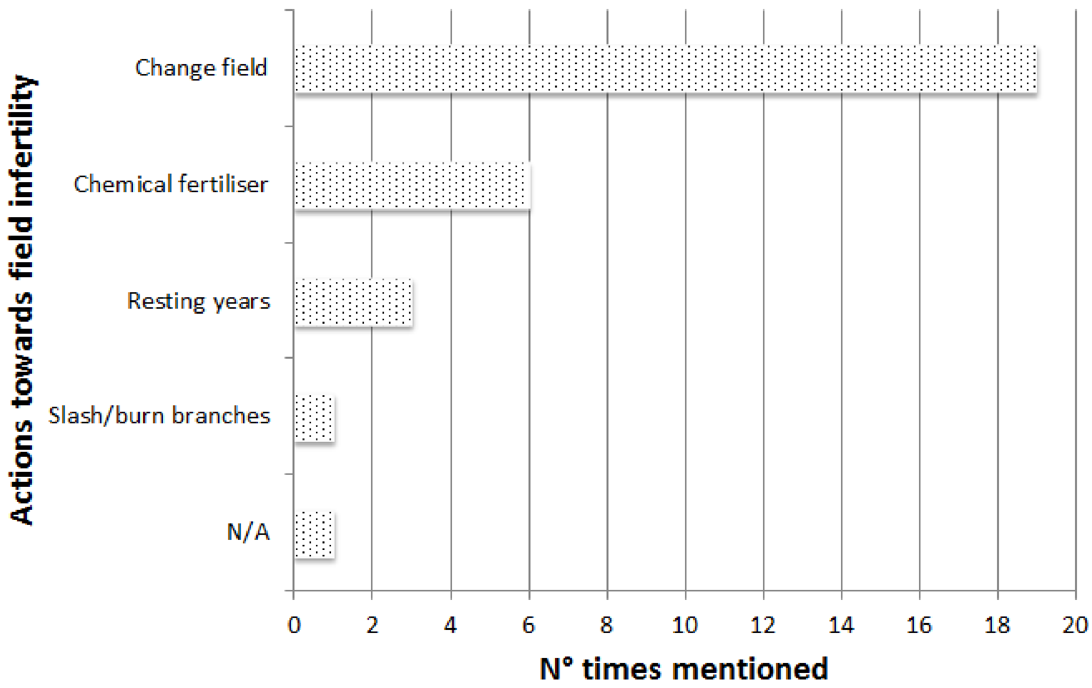

Figure 3.5: Actions taken towards infertility of slash-and-burn fields

Focusing now on which crops were the most important, a total of 35 different crops were mentioned. The data was analysed in three different ways. In the first analysis, the total number of times that each crop was mentioned was accounted, allowing the understanding of how widely this crop was known and used by the local population. According to the obtained results, maize was the most frequently mentioned crop, followed by beans, cowpea and cassava (Figure 3.6). Figure 3.6 only takes in consideration the 10 most referred crops, however, a total of 35 different foods were mentioned. The second analysis grouped only those crops which were mentioned more often in the first position of the lists given by the interviewees. As the results clearly show, the maize is the most important crop in that area with 20 out of 30 answers in the first listing position (Figure A.9). It is then followed by beans, which only gathered five answers on the first position. The third analysis took in consideration the main crops which were mentioned more often on each position of the lists given by the interviewees. According to the results below, maize was the most mentioned crop on the first position, beans were the most referred crops on the second position and cowpea was the most mentioned crop in both the third and fourth positions (Figure A.10). Cassava led the fifth listing position.

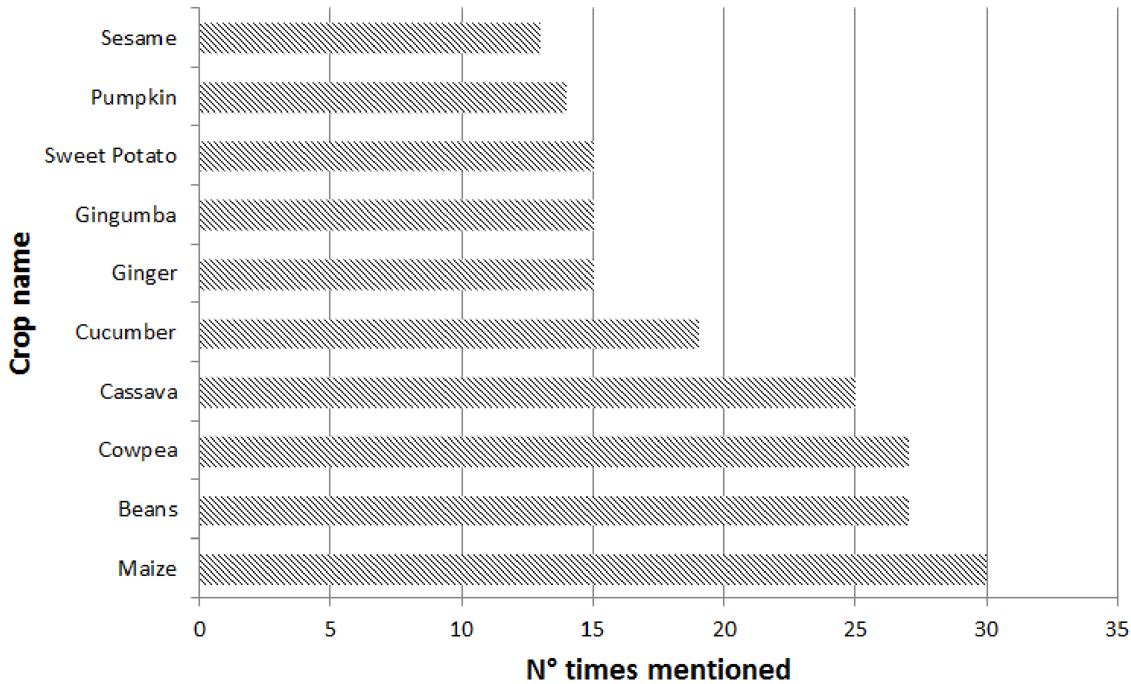

Figure 3.6: Ten most referred crops by interviewees

3.3 Field

Presence-Absence and Species Composition

According to the One-Way ANOVA, recent slash-and-burn fields differed significantly from old fields with regard to the occurrence of key-species (p value = 0.00564). However, there were no significant differences between any other categories.

The PCO analysis (Figure 3.7), together with the Analysis of similarities with R values (Table 3.8), showed that the categories of recent and control formed a clear grouping, even though they still overlapped to some extent ($R = 0.531$). Medium and recent fields show a strong overlap ($R = 0.3746$), just like old and recent ($R = 0.2692$). Finally, when comparing the control group with the categories of medium and old, there was no significant difference, i.e., the categories did not form clear and distinct groups ($R < 0.25$).

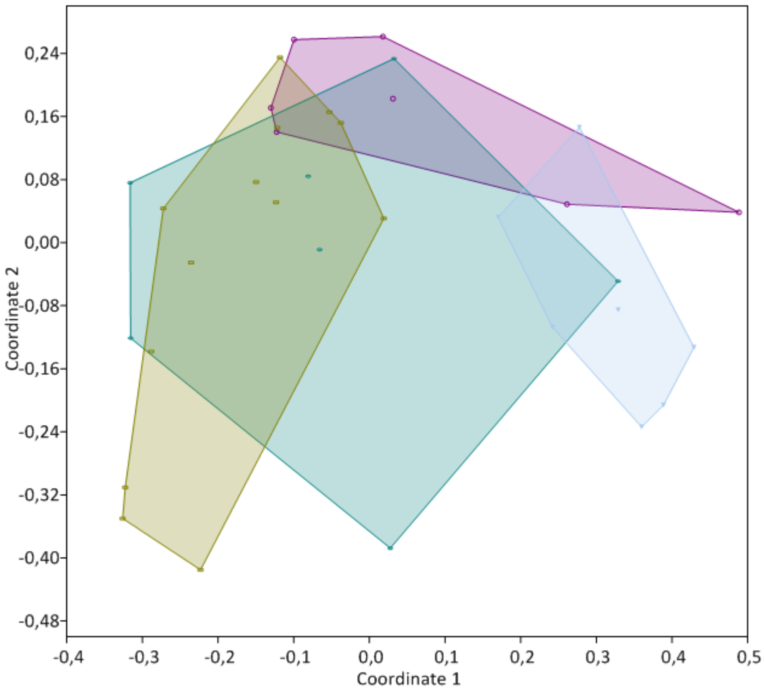

Figure 3.7: PCO analysis for key-species composition (x = 1; y = 2). Colour legend: purple - old plots; green - medium plots; light blue - recent plots; brown - control group

Table 3.8: ANOSIM analysis of field categories with regard to key-species composition (r values)

	Medium	**Recent**	**Control**
Old	0.2255	0.2692	0.1499
Medium		0.3746	-0.00444
Recent			0.531

According to the Analysis of similarities with Bonferroni corrected p values (Table A.2), there were significant dissimilarities between medium and recent plots (p value = 0.0126), and recent and control plots (p value = 0.0006). However, no other comparison between field categories resulted into significant dissimilarities. Table 3.9 summarizes the obtained results through a SIMPER analysis, which shows that *Warneckea sapinii*, *Brachystegia spiciformis*, *Erythrophleum africanum*, *Burkea africana* and *Brachystegia bakeriana* were the key-species which contributed the most to the dissimilarities between field categories (i.e. species with the highest mean "relative presence").

Table 3.9: Key-species which contributed the most to the dissimilarities between field categories in terms of species composition

Comparison	**Key-species**	**Mean "relative presence" higher in**
Old + Medium	*Warneckea sapinii*	Old
Old + Recent	*Warneckea sapinii*	Old
Old + Control	*Brachystegia spiciformis*	Old
Medium + Recent	*Erythrophleum africanum*	Medium
Medium + Control	*Burkea africana*	Medium
Recent + Control	*Brachystegia bakeriana*	Control

Key-Species Coverage

Normality was not found in plant cover data when tested with both the Shapiro-Wilk test and Normal Probability Plots. Therefore, a Kruskal-Wallis (non-parametric) test was used. It was found that all categories were significantly different (p value < 0.05), with the exception of the p value = 0.3844 resulting from the comparison of old and recent fields (Table 3.10). Also, an Analysis of similarities with Bonferroni corrected p values showed that control fields were significantly dissimilar from all those of the other three categories (p value = 0.0012 (old); p value = 0.0006 (medium); p value = 0.0018 (recent)). Table 3.11 summarizes the obtained results through a SIMPER analysis, which showed that *Brachystegia spiciformis* and *Cryptosepalum exfoliatum ssp. pseudotaxus* were the key-species which contributed the most to the dissimilarities between field categories (i.e. species with the highest mean abundance).

Table 3.10: Kruskal-Wallis test comparing key-species' coverage between the different field categories

	Medium	**Recent**	**Control**
Old	0.01088	0.3844	0.0006747
Medium		0.003198	0.0004714
Recent			0.04134

Table 3.11: Key-species which contributed the most to the dissimilarities between field categories in terms of coverage

Comparison	**Key-species**	**Mean abundance higher in**
Old + medium	*Brachystegia spiciformis*	Old
Old + Recent	*Brachystegia spiciformis*	Recent
Old + Control	*Cryptosepalum exfoliatum ssp. pseudotaxus*	Control
Medium + Recent	*Brachystegia spiciformis*	Recent
Medium + Control	*Cryptosepalum exfoliatum ssp. pseudotaxus*	Control
Recent + Control	*Cryptosepalum exfoliatum ssp. pseudotaxus*	Control

Presence-Absence and Coverage

Figure 3.8 joins together both presence-absence and cover values for a better visualization of the results. It shows that the highest number of species was found in old plots, while the highest coverage of the key-species occurred in the control group. Figure 3.9 relates presence-absence with the mean abundance of each key-species, which shows which regenerated in which category and how abundant they were found there. Eighteen out of the 21 key-species were present, with three key-species completely absent in the assessed plots. *Brachystegia spiciformis* and *Cryptosepalum exfoliatum ssp. pseudotaxus* were the two species which were more abundant in the four field categories.

Regeneration type

According to the contingency table, there is a relation between the different categories and the type of regeneration found on the found key-species, X^2 (2, n = 102) = 37,218, p = 0.0001 (a control group was not available for this analysis). In total, 54% of the individuals regenerated in a vegetative way, while 46% did it from a seed. In old slash-and-burn fields, 43 individuals of the key-species were found to be resprouting from seeds, with another 18 presenting vegetative regeneration. In recent slash-and-burn fields, 23 individuals presented vegetative regeneration and only 4 were found to be resprouting from seed (Figure 3.10). It was only found vegetative regeneration (14) in medium fields.

Height - 10 x 10 m and 50 x 20 m

In general, 10 x 10 m old plots had on average higher trees (from both vegetative and seed regeneration) than those from the other two categories (data for the control group were not available for this analysis) (Figure 3.11). In its turn, medium and recent plots contained, on average, trees with similar heights. Nevertheless, less key-species with at least 1 m height were found in medium slash-and-burn fields. Looking closer to which species were contributing the most for these height differences between field categories, it is possible

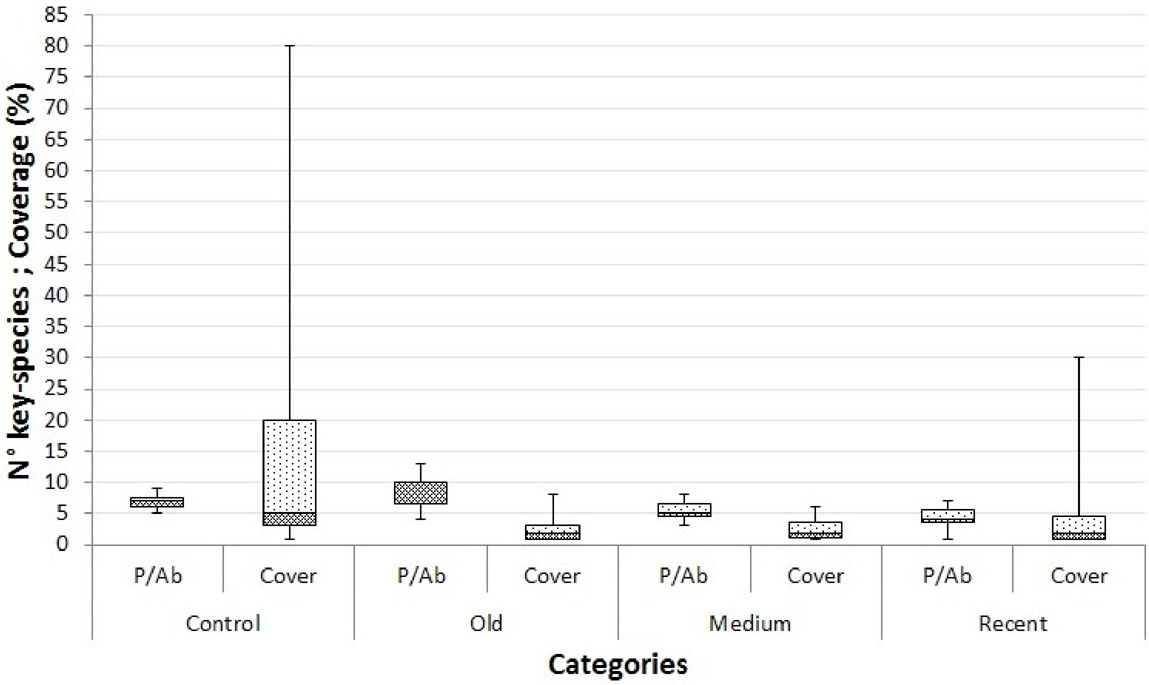

Figure 3.8: Presence-absence (P/Ab) and coverage of key-species in the four field categories

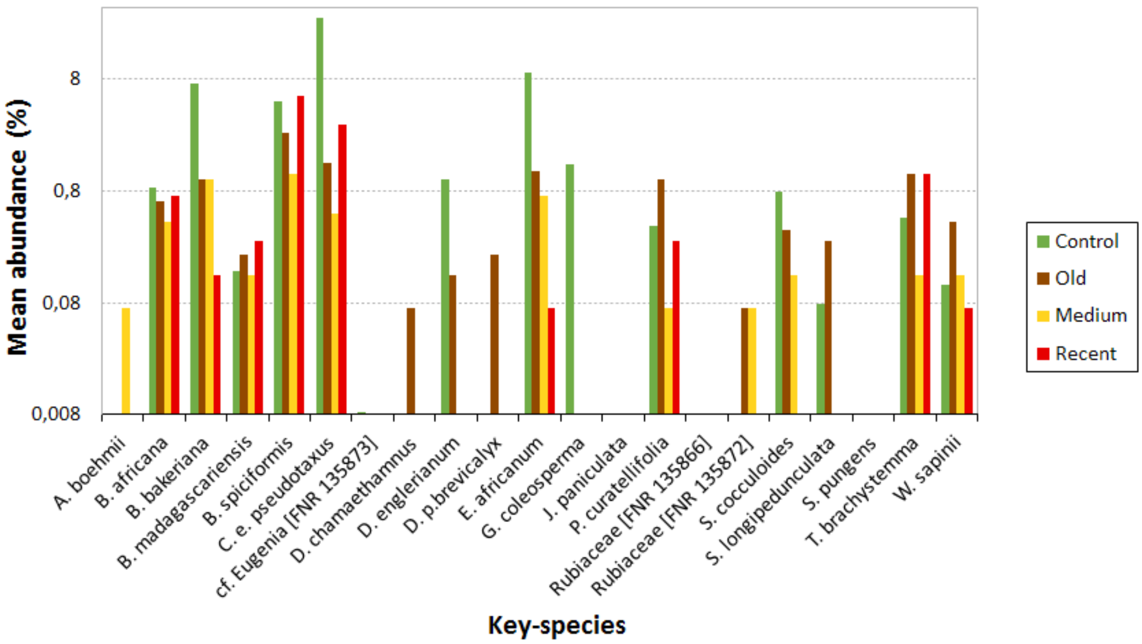

Figure 3.9: Key-species' presence-absence in each field category and their mean abundance (logarithmic scale)

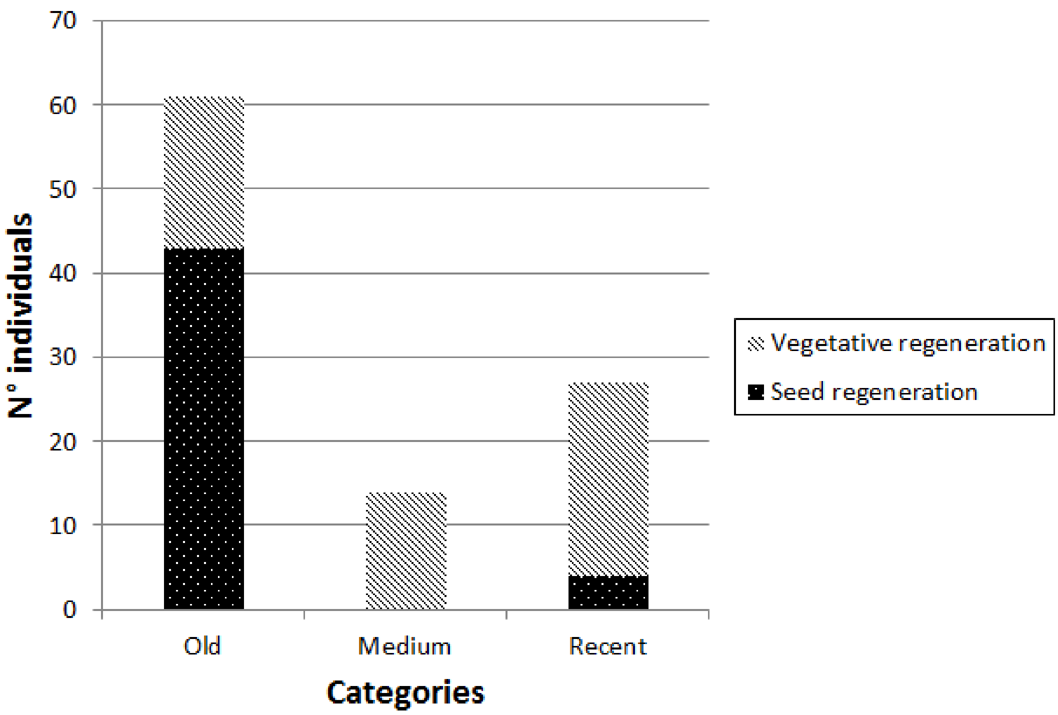

Figure 3.10: Barchart with the main regeneration types inside each field category

to see that *Parinari curatellifolia* was the highest species in old plots (Figure 3.11). The highest tree in medium plots was *Brachystegia spiciformis*, and in recent plots it was *Terminalia brachystemma*. *Brachystegia spiciformis*, *Brachystegia bakeriana* and *Erythrophleum africanum* were present in all categories (Figure 3.11). *Terminalia brachystemma*, *Burkea africana* and *Cryptosepalum exfoliatum ssp. pseudotaxus* were present in only two of the three categories, and *Parinari curatellifolia*, *Dialium englerianum* and *Bobgunnia madagascariensis* were only found in old plots (with more than 1 meter height). Only nine out of the 21 key-species managed to reach at least 1 m height.

Old and recent 50 x 20 m plots had on average higher trees than medium plots (control was not possible for this analysis) (Figure 3.12). Looking closer to which species were contributing the most for this height difference, it is possible to see that *Brachystegia spiciformis* was the highest species in old plots (Figure 3.12). The highest tree in recent plots was *Brachystegia spiciformis* as well, and in medium plots it was *Dialium englerianum* (only one individual). No non-slashed key-species trees appeared in all categories. *Brachystegia spiciformis* and *Dialium englerianum* occurred in only two categories, while *Parinari curatellifolia* was only found in recent plots and *Burkea africana*, *Erythrophleum africanum* e *Cryptosepalum exfoliatum ssp. pseudotaxus* only in old plots (Figure 3.12). Only six non-slashed individuals out of the 21 key-species reached at least 50 cm of perimeter.

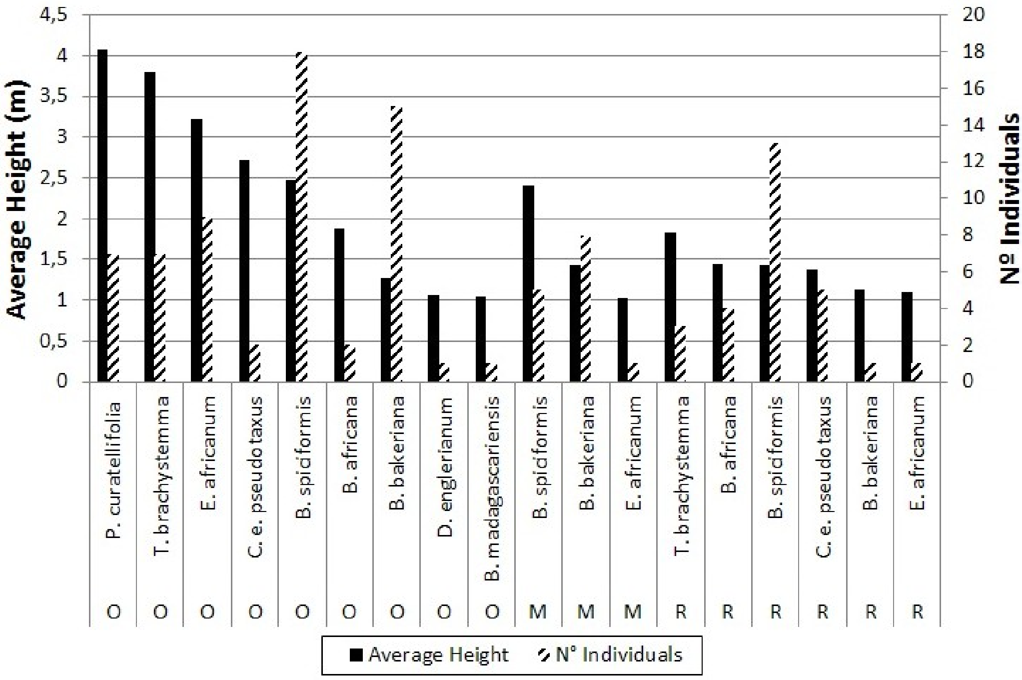

Figure 3.11: Height and abundance of selected key-species in the different field-age categories (10 x 10 m plots)

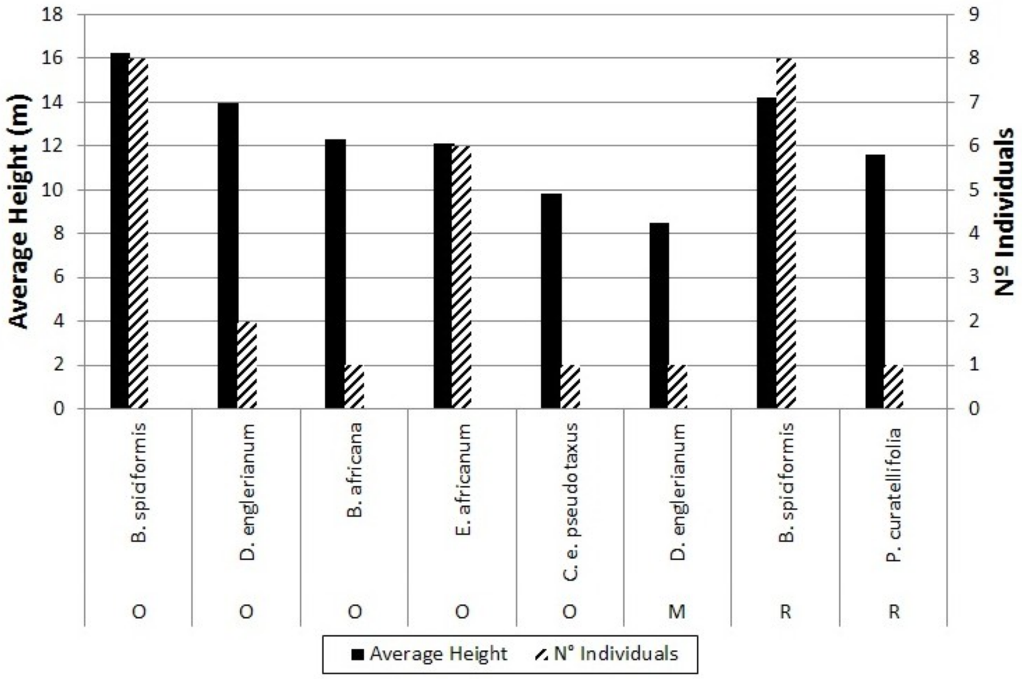

Figure 3.12: Height and abundance of selected key-species in the different field-age categories (50 x 20 m plots)

Chapter 4

Discussion

The main purpose of this study was to assess if the practise of slash-and-burn agriculture by the local communities in the Cusseque area impacts the regeneration of a selected group of woody key-species. Previous studies have approached the negative impacts of slash-and-burn agriculture in forests, connecting it to soil and land degradation and biodiversity losses [11] [12] [13] [14]. This present study suggests that shifting agriculture does impact the natural vegetation to some extent in the Cusseque area. According to Kennard et al [24], the kind of disturbance applied in a patch of forest influences the patterns of forest regeneration. In the Cusseque area, it was found that forest patches for agriculture are usually burned twice, fields are used for about 1 to 3 years and resting years do not usually exceed 3 years. This suggests some fire intensity and a short fallow period, the later being cited by several authors as one of the main reasons for the non-sustainability of this form of agriculture due to leading to soil nutrient loss and land degradation [4] [12] [25].

Less regeneration from seed banks was found in recent fields compared to old ones. Fire has been linked to the killing of seeds in surface soils, this way affecting plant regeneration after severe disturbances [24]. Therefore, it is possible to assume that seed banks are affected by fire in the Cusseque area, specially taking in consideration that two fire events are held per patch of forest. Additionally, stump sprouts are also affected after slash-and-burn events [24]. In the present study, vegetative regeneration was found to be predominant (54%), however not with a high lead over seed regeneration (46%). It is then possible to speculate that if fire was suppressed and only slash took place, vegetative regeneration would be stronger, specially in recent plots. Therefore, it would be interesting to test this hypothesis in further studies.

Key-species were found to regenerate across the age categories, however, less key-species were found in the control group compared to old fields. According to the Intermediate Disturbance Hypothesis (IDH), species diversity peaks at intermediate disturbance levels [26]. Old fields are no longer subjected to slash and burn, therefore reducing disturbance intensity and allowing a growing in species richness. Moreover, when compared to non-disturbed forest, old plots are still under a certain level of disturbance since canopy is not closed and therefore allowing less shade-tolerant species to coexist with forest-like species. This way, the number of key-species found in old fields surpass those in the control group because the old fields have the needed conditions to lodge both competitive and disturbance tolerant key-species [26].

Except for old and recent plots, all other field categories were significantly different in terms of key-species cover values. This exception might be explained due to the fact that recent plots contained an outlier. The raw results from field 7 confirm that *Brachystegia spiciformis* (30% coverage) is the main outlier. This is in accordance with the SIMPER results for coverage (Figure 3.11), where *Brachystegia spiciformis* was the key-species which contributed the most to the dissimilarities between field categories and its mean abundance was higher in recent plots. According to the field notes, all trees were slashed in the 10 x 10 m plot where coverage was assessed. Landsat Satellite Imagery helped to refute the possibility of field 7 to be misplaced in its age category. Therefore, since this was an exceptional case, it is possible to speculate that *Brachystegia spiciformis* regenerated quicker in that field due to local conditions or perhaps local people did slash those trees but not burn them as much as usual, therefore not damaging the cut trunks so much [24]. Interestingly, four out of seven old fields were densely covered by ferns and some grasses (Figures 2.5 and 4.1). The fern *Pteridium aquilinum* has been linked to the retardation of forest regeneration and to its negative impacts over tree and shrub species richness and abundance [27] [28]. Therefore, the presence of this fern may be linked to the low cover values in older fields, when compared to medium and recent fields.

Figure 4.1: Fallow covered with ferns (*Pteridium aquilinum*)

Species composition is significantly dissimilar between recent fields and medium fields, *Erythrophleum africanum* contributing the most to these dissimilarities (Table 3.9). Very few studies have been done about *Erythrophleum africanum*, most of them regarding its toxicological properties [29] [30]. This species was often described by local communities as "pau ferro", meaning it was too difficult to cut. Its resistance was also appreciated by locals, therefore being used for the construction of houses, as seen in table 3.1. In fact, *Erythrophleum africanum* was the most mentioned and used key-species by interviewees 3.2. This way, it is possible to suggest that this tree is less cut due to its resistance - something described very often by locals - or it is let to regenerate earlier than other tree species due to its usage importance for traditional communities.

Figure 3.9 shows that nine key-species were found in recent fields and twelve in medium fields. *Strychnos cocculoides*, *cf. Rubiaceae* and *Anisophyllea boehmii* were exclusively present in medium plots and, according to table 3.1, they were all referred as important wild fruit trees. No studies were found to relate seed dispersal by humans and fruit tree regeneration in the tropics. Nevertheless, Auffret and Cousins [31] stated, in the context of rural communities in Sweden, that humans can indeed work as seed dispersers, contributing to the dispersal of a high proportion of the seeds of local plants. Therefore, it is possible to suggest that local people in the Cusseque area work as seed dispersers, since fruits are collected in the forest and might then be transported to the working fields either with the purpose for later consumption or indirectly through their digestion.

Species composition is significantly dissimilar between recent fields and the control group as well, *Brachystegia bakeriana* contributing the most to these dissimilarities (Table 3.9). Very little is known about *Brachystegia bakeriana*. However, as seen in table 3.9, this species was present more often in control plots. Also, figure 3.9 shows a gradual growth of abundance from recent fields to control fields, suggesting that this species is able to regenerate after slash and burn but prefers forest-like conditions to live. According to figure 3.9, nine species were common in both recent and control categories. The control group added up five more key-species in relation to recent plots, which were *Guibourtia coleosperma*, *Dialium englerianum*, *cf. Eugenia*, *Strychnos cocculoides* and *Securidaca longipedunculata*. These key-species were only present in either the control group and old fields, with the exception of *Strychnos cocculoides* which was found in medium fields as well and has been described as a light demanding species [32]. This suggests a sensitivity to slash-and-burn practises and a potential dependency of *G. coleosperma*, *D. englerianum*, *cf. Eugenia* and *S. longipedunculata* on forest-like conditions to thrive. When abundance was analysed through species composition, the control group was the highlighted category with higher cover values, *Cryptosepalum exfoliatum ssp. pseudotaxus* contributing the most to this dissimilarity (Figure 3.11) and suggesting a close relation between this species and forest-like conditions.

More key-species reached greater heights in old slash-and-burn fields, comparing to medium and recent fields. This difference was larger in 10 x 10 m plots since most measured trees had been slashed and vegetative regeneration was predominant (Figures 3.10 and 2.8). Only nine out of the 21 key-species managed to reach at least 1 m height and only six out of the 21 key-species (non-slashed individuals) reached at least 50 cm of perimeter. Moreover, *Brachystegia spiciformis*, *Cryptosepalum exfoliatum ssp. pseudotaxus*, *Erythrophleum africanum*, *Burkea africana* and *Dialium englerianum* regenerated in 10 x 10 m old plots but, when compared with 50 x 20 m plots, they were still far from their potential heights (Figure 3.12) [33]. As referred earlier in this discussion, stump sprouts are affected by slash and burn [24] and vegetative regeneration was predominantly found in this study. This way, these results seem to reinforce that slash and burn does impact key-species regeneration to some extent.

The use of the free-listing method revealed a wealth of traditional knowledge on useful plants amongst Chokwe people in the Cusseque area. Previous studies on different rural communities in Africa have shown an interdependency between these communities and their local forests [34] [35] [36] [37] [38] [39], and the present free-listing results seem to indicate the same for the studied traditional communities, specially due to the high incidence of poverty in the basin [2]. For instance, wild fruit trees have been related to a better nutrition in other rural communities [40] and, in the present study, it was found that eleven out of the 21 key-species were trees whose fruit was consumed by local people (Table 3.1). Therefore, these wild trees might be extremely important nutritional supplements to their staple diet composed by mainly maize, beans, cowpea and cassava (Figure 3.6). Another example is the traditional use of wild plants for medicinal purposes, which has been documented in previous studies [41] [42] [43] and which is also present in the studied communities, as 13 out of the 21 key-species were said to be used to treat health problems. Therefore, medicinal wild trees work as a primary health care in the area. Excluding *cf. Eugenia* [FNR 135873], Rubiaceae [FNR 135866] and cf. Rubiaceae [FNR 135872] due to the incomplete species identification, all key-species were looked up in the IUCN Red List and only *Brachystegia bakeriana* has already been assessed, being categorized as Vulnerable since 1998 [44]. This demonstrates the huge lack of data regarding species in the Cusseque area as well as in other parts of Angola and Africa, and therefore further research in the area is critical for an efficient conservation of these species.

Chapter 5

Conclusions and Final Considerations

This study suggests that slash-and-burn agriculture impacts to some extent the regeneration of the key-species. However, the lack of information regarding most of the key-species limited the understanding of regeneration dynamics. Therefore, more botanical studies in the region are needed to help closing this knowledge gap. This study also contributed to a better understanding of how slash-and-burn agriculture occurs in the area and what particularities are present there. This kind of information will be relevant to support further research related to farming practises and their impact on the natural vegetation of that area. Also, the findings related to traditional knowledge of local people highlights the importance of documenting these wisdom, which otherwise might be lost forever. Due to the fact that this study was restricted to a small number of key-species, results cannot be generalized out of the study area. Nevertheless, these findings are definitely helpful to support future research on the core site.

Recommendantions for future research include enlarging the number of studied species, add more questions on semi-structured enquiries regarding local people ideas and perceptions about their surrounding natural forests and include more regeneration parameters (e.g. tree mortality, survival and recruitment of seedlings) in order to fully understand the impact of slash-and-burn in the area.

Bibliography

[1] Kabii, T. 1997. Okavango - the world's largest Ramsar site. Ramsar (Ramsar Convention on Wetlands), Gland. Available from http://www.ramsar.org/ [accessed September 2013].

[2] Kgathi, D., D. Kniveton, S. Ringrose, A. Turton, C. Vanderpost, J. Lundqvist, and M. Seely. 2006. The Okavango; a river supporting its people, environment and economic development. Journal of Hydrology 331:3-17.

[3] Abdelli, H. and D. Jouen. 2012. Diagnóstico agrário territorial da província do Bié: Municípios do Andulo e Chitembo. FAO (Food and Agriculture Organization of the United Nations), Rome.

[4] Brady, N. 1996. Alternatives to slash-and-burn: A global imperative. Agriculture Ecosystems & Environment 58:3-11.

[5] Turner, I. M. 1996. Species loss in fragments of tropical rainforest: a review of the evidence. Journal of Applied Ecology 33:200-209.

[6] Giam, X., C. Bradshaw, H. Tan, and N. Sodhi. 2010. Future habitat loss and the conservation of plant biodiversity. Biological Conservation 143:1594-1602.

[7] WWF (World Wildlife Fund). 2012. Living Planet Report 2012: Biodiversity, biocapacity and better choices. WWF, Switzerland.

[8] Kettle, C. 2012. Seeding ecological restoration of tropical forests: Priority setting under REDD+. Biological Conservation 154:34-41.

[9] De Baan, L., R. Alkemade, and T. Koellner. 2013. Land use impacts on biodiversity in LCA: a global approach. International Journal of Life Cycle Assessment 18:1216-1230.

[10] Universität Hamburg. 2011. The Future Okavango (TFO) - Progress Report 2011. Research Programme *Sustainable Land Management*, Hamburg.

[11] Juo, A., and A. Manu. 1996. Chemical dynamics in slash-and-burn agriculture. Agriculture Ecosystems & Environment 58:49-60.

[12] Tinker, P., J. Ingram, and S. Struwe. 1996. Effects of slash-and-burn agriculture and deforestation on climate change. Agriculture Ecosystems & Environment 58:13-22.

[13] Vosti, S. A. and J. Witcover. 1996. Slash-and-burn agriculture - household perspectives. Agriculture, Ecosystems and Environment 58:23-38.

[14] Kleinman, P., D. Pimentel, and R. Bryant. 1995. The ecological sustainability of slash-and-burn agriculture. Agriculture Ecosystems & Environment 52:235-249.

[15] TFO (The Future Okavango Project), Hamburg. Available from http://www.future-okavango.org/ [accessed September 2013].

[16] Timberlake, J. 2000. Biodiversity of the Zambezi Basin. Biodiversity Foundation for Africa, Famona, Bulawayo.

[17] Ministério do Urbanismo e Ambiente. 2006. Primeiro Relatório Nacional para a Conferência das Partes da Convenção da Diversidade Biológica. Ministério do Urbanismo e Ambiente. Luanda.

[18] Quinlan, M. 2005. Considerations for collecting free-lists in the field: examples from ethnobotany. Field Methods, Journal 17 (3):1–16.

[19] Chidumayo, E. N. 1997. Miombo Ecology and Management, an Introduction. IT Publications. Second edition. ITDG Publishing, London.

[20] Barriball, K., and A. While. 1994. Collecting data using a semistructured interview - A discussion paper. Journal of Advanced Nursing 19:328-335.

[21] Hammer, Ø., Harper, D.A.T., Ryan, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

[22] Razali1, N. M. and Y. B. Wah. 2011. Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. Journal of Statistical Modeling and Analytics, Journal 2 (1):21-33.

[23] McCune, B., Grace, J. B. and D. L. Urban. 2002. Analysis of Ecological Communities. MjM Software Design, USA.

[24] Kennard, D., K. Gould, F. Putz, T. Fredericksen, and F. Morales. 2002. Effect of disturbance intensity on regeneration mechanisms in a tropical dry forest. Forest Ecology and Management 162:197-208.

[25] Harwood, R. 1996. Development pathways toward sustainable systems following slash-and-burn. Agriculture Ecosystems & Environment 58:75-86.

[26] Kershaw, H., and A. Mallik. 2013. Predicting Plant Diversity Response to Disturbance: Applicability of the Intermediate Disturbance Hypothesis and Mass Ratio Hypothesis. Critical Reviews in Plant Sciences 32:383-395.

[27] Yassir, I., J. van der Kamp, and P. Buurman. 2010. Secondary succession after fire in Imperata grasslands of East Kalimantan, Indonesia. Agriculture Ecosystems & Environment 137:172-182.

[28] Ribeiro, S., S. Botelho, M. Fontes, P. Garcia, and H. Almeida. 2013. Natural regeneration of deforested areas dominated by *Pteridium aquilinum* (L.) Kuhn located in the Serra da Mantiqueira Mountain range. Cerne 19:65-76.

[29] Hassan, S. W., Ladan, M.J., Dogondaji, R. A., Umar, R. A., Bilbis, L. S., Hassan, L. G., Ebbo, A. A. and I. K. Matazu. Phytochemical and toxicological studies of aqueous leaves extracts of *Erythrophleum africanum*. Pakistan Journal of Biological Sciences 10:3815-3821.

[30] Kadja, A., J. Mamyrbekova-Bekro, A. Benie, B. Boua, K. N'Gaman, and Y. Bekro. 2011. *Erythrophleum africanum* Afzel. (Caesalpiniaceae), an African toothpick: Phytochemical screening, total flavonoid content and antioxidant activity. Journal of Medicinal Plants Research 5:6273-6277.

[31] Auffret, A., and S. Cousins. 2013. Humans as Long-Distance Dispersers of Rural Plant Communities. Plos One 8.

[32] Hines, D. A. and K. Eckman. 1993. Indigenous multipurpose trees of Tanzania: uses and economic benefits for people. FAO (Food and Agriculture Organization of the United Nations), Rome. Available from http://www.fao.org/docrep/x5327e/x5327e1k.htm [accessed September 2013].

[33] Palgrave, K. C. 2000. Trees of Southern Africa. Second edition. Struik Publishers, Cape Town.

[34] Rasethe, M., S. Semenya, M. Potgieter, and A. Maroyi. 2013. The utilization and management of plant resources in rural areas of the Limpopo Province, South Africa. Journal of Ethnobiology and Ethnomedicine 9.

[35] Lykke, A. 2000. Local perceptions of vegetation change and priorities for conservation of woody-savanna vegetation in Senegal. Journal of Environmental Management 59:107-120.

[36] Obiri, J., M. Lawes, and M. Mukolwe. 2002. The dynamics and sustainable use of high-value tree species of the coastal Pondoland forests of the Eastern Cape Province, South Africa. Forest Ecology and Management 166:131-148.

[37] Shackleton, C., S. Shackleton, E. Buiten, and N. Bird. 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. Forest Policy and Economics 9:558-577.

[38] De Beer, J., and B. Van Wyk. 2011. An ethnobotanical survey of the Agter-Hantam, Northern Cape Province, South Africa. South African Journal of Botany 77:741-754.

[39] Houehanou, T., A. Assogbadjo, R. Kakai, M. Houinato, and B. Sinsin. 2011. Valuation of local preferred uses and traditional ecological knowledge in relation to three multipurpose tree species in Benin (West Africa). Forest Policy and Economics 13:554-562.

[40] Goenster, S., M. Wiehle, K. Kehlenbeck, R. Jamnadass, J. Gebauer, A. Buerkert, J. Wesonga, and R. Kahane. 2011. Indigenous Fruit Trees in Homegardens of the Nuba Mountains, Central Sudan: Tree Diversity and Potential for Improving the Nutrition and Income of Rural Communities. I All Africa Horticultural Congress 911:355-364.

[41] Maroyi, A. 2013. Use of weeds as traditional vegetables in Shurugwi District, Zimbabwe. Journal of Ethnobiology and Ethnomedicine 9.

[42] De Wet, H., S. Nciki, and S. van Vuuren. 2013. Medicinal plants used for the treatment of various skin disorders by a rural community in northern Maputaland, South Africa. Journal of Ethnobiology and Ethnomedicine 9.

[43] Abdillahi, H., and J. Van Staden. 2013. Application of Medicinal Plants in Maternal Healthcare and Infertility: A South African Perspective. Planta Medica 79:591-599.

[44] Phiri, P.S.M. 1998. Brachystegia bakeriana. IUCN (IUCN Red List of Threatened Species), Version 2013.1., Gland. Available from http://www.iucnredlist.org/ [accessed September 2013].

Appendix A

Data: __/__/__ **Nome:**
Inquérito numero ____ **Idade:**
Vila: _________________________ **Ocupação:**

1) Descrição de como é que os campos são preparados para a agricultura.
  a. Existem anos de repouso?

2) Qual é o melhor local para um campo?
  a. Qualquer local é bom.
  b. Dentro da floresta.
  c. Fora da floresta, perto do rio.
  d. Outro.

3) São todas as árvores cortadas antes da queima? _______________
  a. Se não, porque deixam algumas inteiras?
  b. Porque não arranca todo o tronco das árvores?
  c. Porque queima a madeira cortada? Esta tem algum outro uso?

4) Quantas vezes cultiva no mesmo campo por ano? ________________

5) Durante quantos anos usa o mesmo campo para lavrar? ____________________

6) De todo o campo queimado, quanto é usado para a primeira lavra?
  a. Todo o campo é usado.
  b. Metade do campo é usado.
  c. Outro: ____

7) De todo o campo queimado, quanto é usado para a segunda lavra?
  a. Todo o campo é usado.
  b. Metade do campo é usado.
  c. Outro: ____

8) De todo o campo queimado, quanto é usado para a terceira lavra?
  a. Todo o campo é usado.
  b. Metade do campo é usado.
  c. Outro:____

9) Se aplicável: De todo o campo queimado, quanto é usado para a quarta lavra?
  a.

10) Depois do campo queimado, como é feita a lavra?

11) Que tipo de estrume utiliza?

12) Como explora o campo?
  a. Até ao limite.
  b. Sempre o mesmo número de vezes (e.g. 2 anos, 3 anos), independentemente do solo ainda dar para a lavra.
  c. Outro

13) Quando o campo fica infértil, o que faz? Qual são os critérios para mudar de campo?

14) Quais são as principais culturas que cultiva?

Figure A.1: Questions of the semi-structured enquiry (original Portuguese version)

Date: __/__/__ **Name:**
Enquiry number ____ **Age:**
Village: ______________________ **Occupation:**

1) Description of how fields are prepared for cropping.
   a. Are there resting years?

2) What is the best place for a field?
   a. Any place is good.
   b. Forest is better.
   c. Outside of the forest, nearby the river is better.
   d. Other.

3) Are all trees slashed before burning? ______________
   a. If not, why?
   b. Why slash trees around waist height?
   c. Why burn the slashed wood? Is it used for other purposes as well?

4) How many times do you crop in the same field per year? _______________

5) How many years do you use the same field for cropping? _______________

6) Of all the burned field, how much do you really use for the first cropping season?
   a. The whole field is used.
   b. Half of the field is used.
   c. Other: ____

7) Of all the burned field, how much do you really use for the second cropping season?
   a. The whole field is used.
   b. Half of the field is used.
   c. Other: ____

8) Of all the burned field, how much do you really use for the third cropping season?
   a. The whole field is used.
   b. Half of the field is used.
   c. Other: ____

9) If applicable: Of all the burned field, how much do you really use for the _?_ cropping season?
   a. The whole field is used.
   b. Half of the field is used.
   c. Other: ____

10) After the field preparation, how does cropping proceed?

11) What kind of manure do you use?

12) How do you exploit the field?
   a. Until its fertility limit.
   b. Always the same number of times (e.g. 2 years, 3 years), even if the soil is still good for cropping.
   c. Other.

13) When the field is infertile, what do you do? What are the main criteria to leave a field?

14) What are your main crops?

Figure A.2: Questions of the semi-structured enquiry (translated English version)

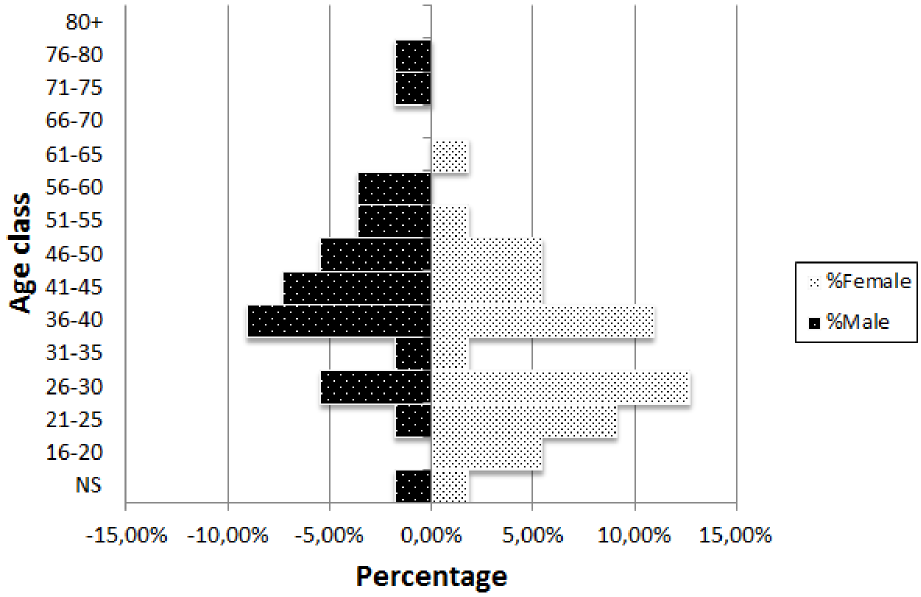

Figure A.3: Age of the participants of the free-listing exercise

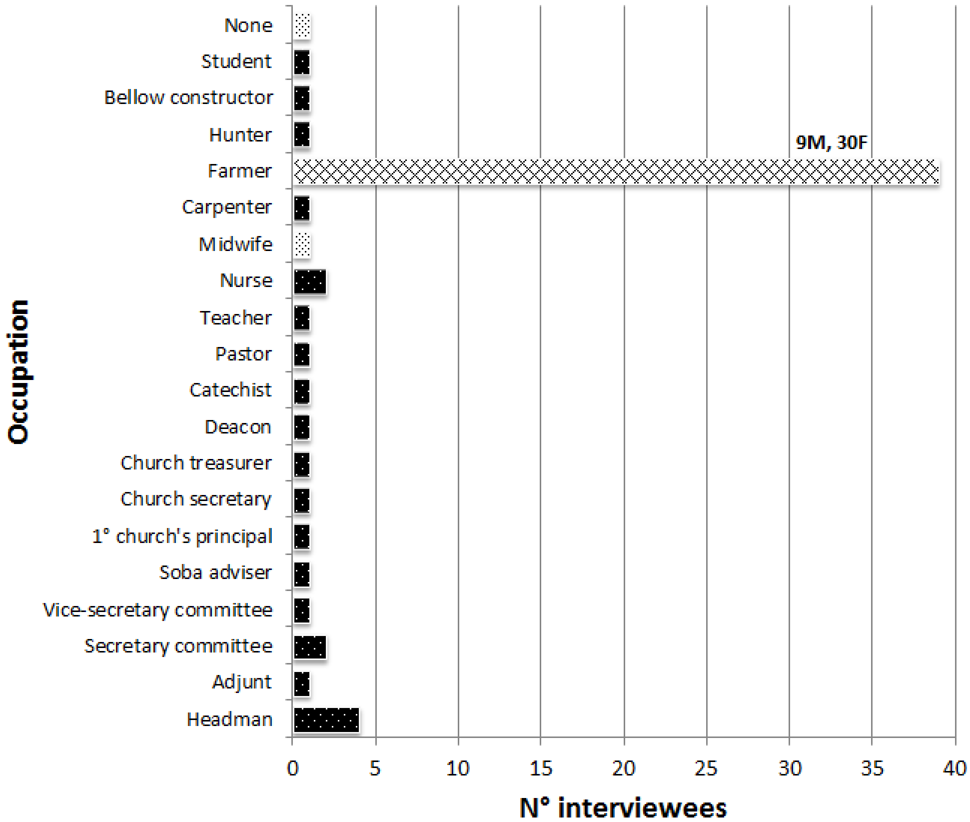

Figure A.4: Main job occupations of the participants of the free-listing exercise

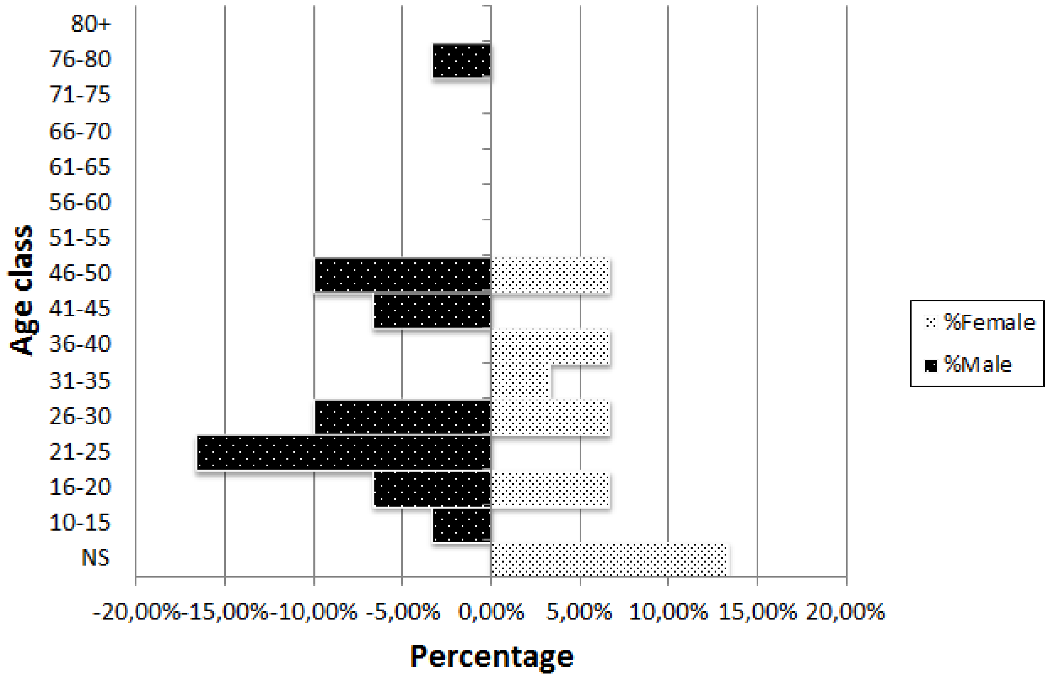

Figure A.5: Age of the interviewees of the slash-and-burn enquiries

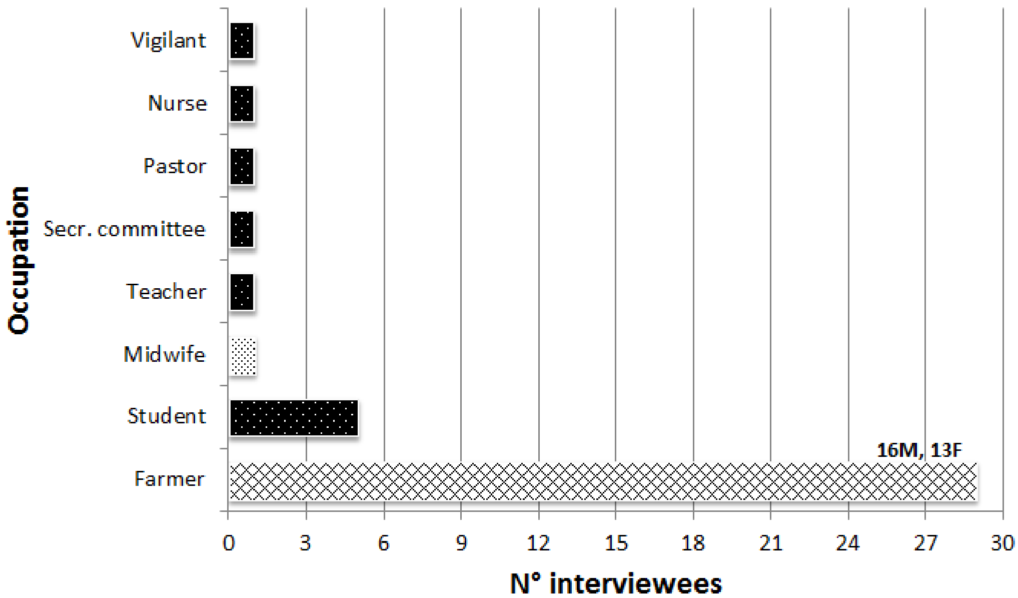

Figure A.6: Main job occupations of the interviewees of the slash-and-burn enquiries

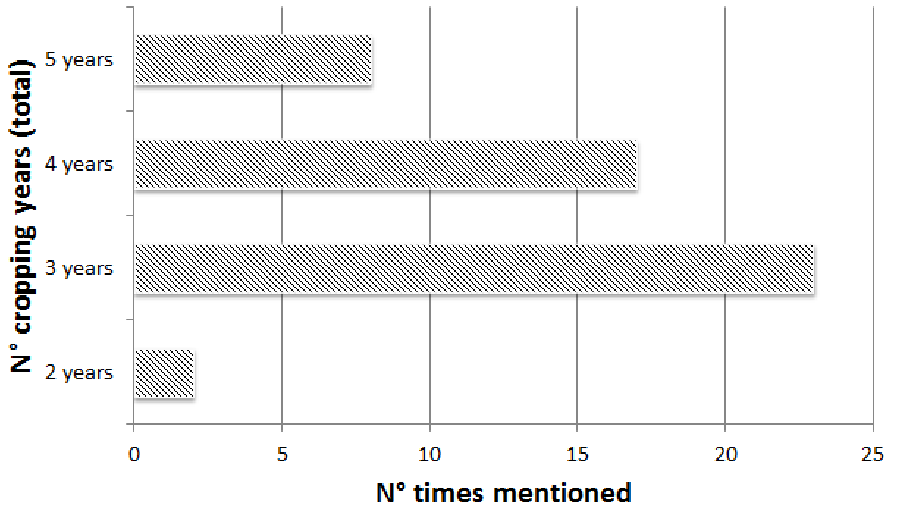

Figure A.7: Utmost number of cropping years before moving out to a new field

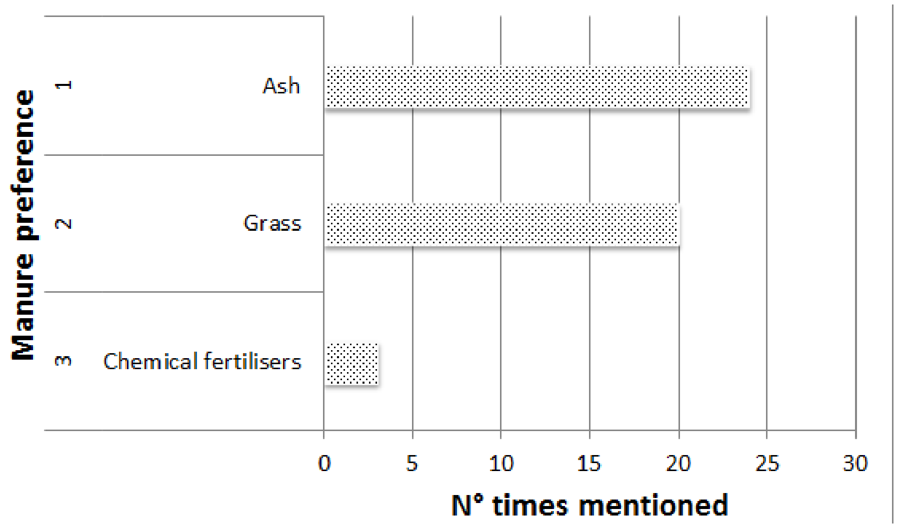

Figure A.8: Main sources of manure taking into consideration the position of each answer in the lists given by the interviewees

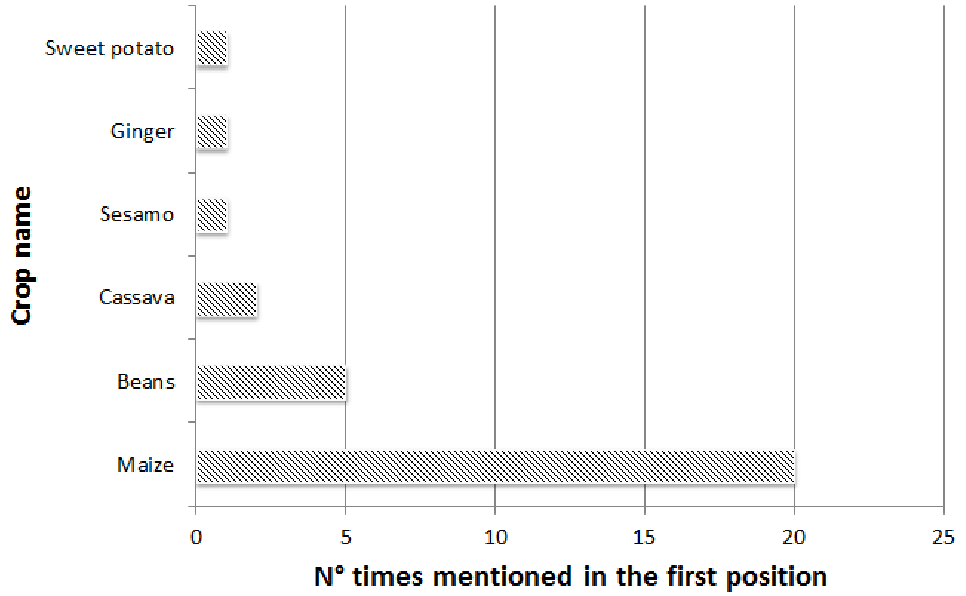

Figure A.9: Crops which were mentioned more often in the first position of the lists given by the interviewees

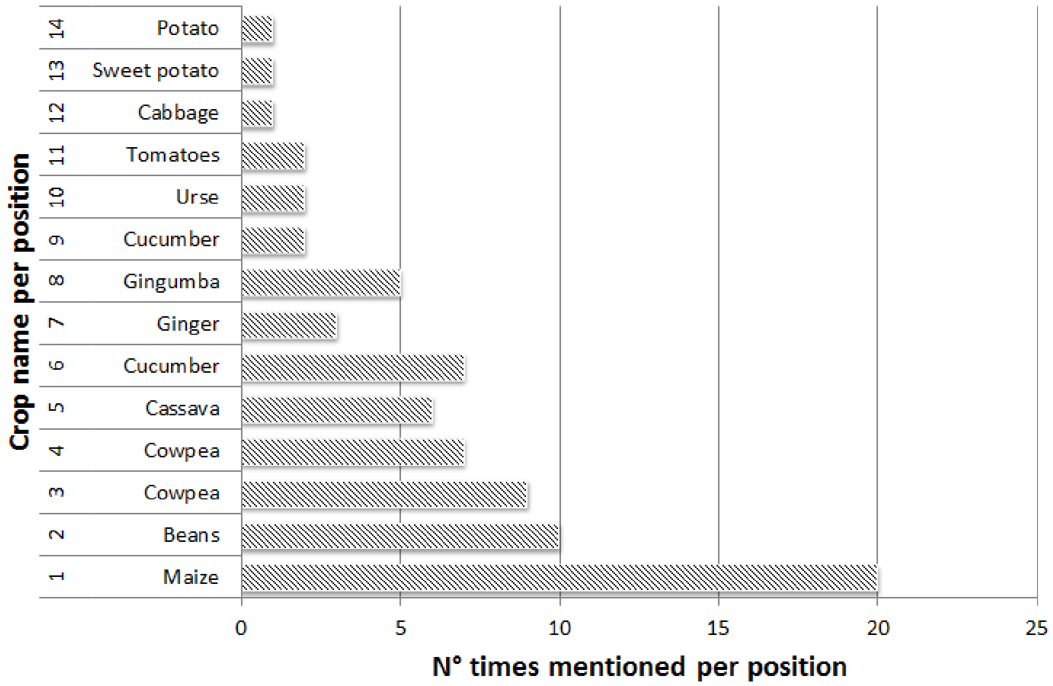

Figure A.10: Crops which were mentioned more often on each position of the lists given by the interviewees

Table A.1: GPS coordinates of used slash-and-burn fields and non-disturbed forest locations (control group)

Name	Category	Latitude	Longitude
23280	Control	S13.69	E17.04
23287	Control	S13.70	E17.07
23298	Control	S13.69	E17.07
23299	Control	S13.69	E17.06
23300	Control	S13.68	E17.07
23302	Control	S13.69	E16.98
23303	Control	S13.69	E16.98
23304	Control	S13.70	E16.98
23305	Control	S13.69	E17.01
23383	Control	S13.70	E17.03
23395	Control	S13.69	E17.04
23477	Control	S13.68	E17.05
23487	Control	S13.70	E16.96
Field 8 (Set 2005)	Old	S13.69	E17.07
Field 9 (Set 2003)	Old	S13.69	E17.07
Field 12 (Set 2003)	Old	S13.70	E17.07
Field 13 (Set 2006)	Old	S13.70	E17.07
Field 26 (Set 2006)	Old	S13.70	E17.05
Field 28 (Set 1900´s)	Old	S13.70	E17.05
Field 29 (Set 1900´s)	Old	S13.70	E17.05
Field 30 (Set 2008)	Medium	S13.70	E17.05
Field 31 (Set 2008)	Medium	S13.70	E17.05
Field 33 (Set 2009)	Medium	S13.70	E17.05
Field 35 (Set 2009)	Medium	S13.69	E17.06
Field 36 (Set 2009)	Medium	S13.69	E17.06
Field 37 (Set 2009)	Medium	S13.68	E17.05
Field 38 (Set 2009)	Medium	S13.68	E17.05
Field 5 (Set 2011)	Recent	S13.70	E17.07
Field 7 (Set 2011)	Recent	S13.70	E17.07
Field 14 (Set 2011)	Recent	S13.70	E17.07
Field 16 (set 2010)	Recent	S13.70	E17.06
Field 17 (Set 2010)	Recent	S13.70	E17.06
Field 18 (Set 2010)	Recent	S13.70	E17.06
Field 21 (Set 2011)	Recent	S13.70	E17.07

Table A.2: ANOSIM analysis on species composition with Bonferroni corrected p values

	Medium	**Recent**	**Control**
Old	0.1146	0.1014	0.4602
Medium		0.0126	1
Recent			0.0006